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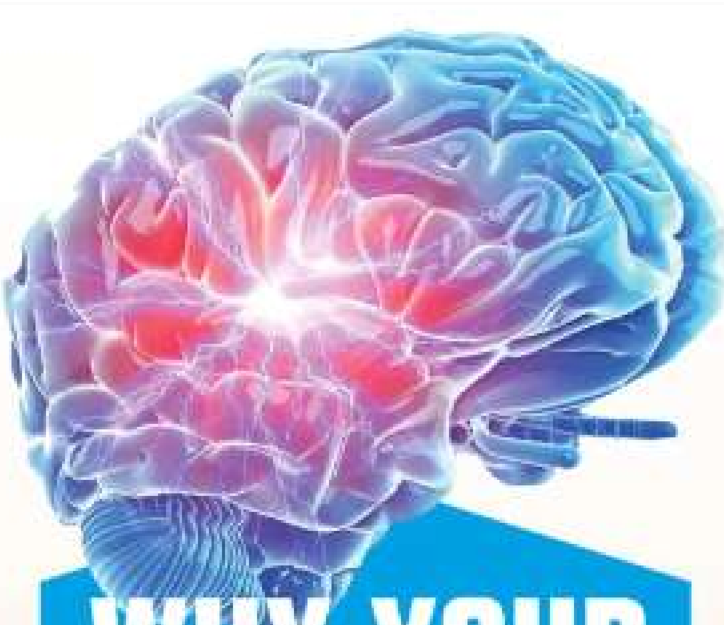

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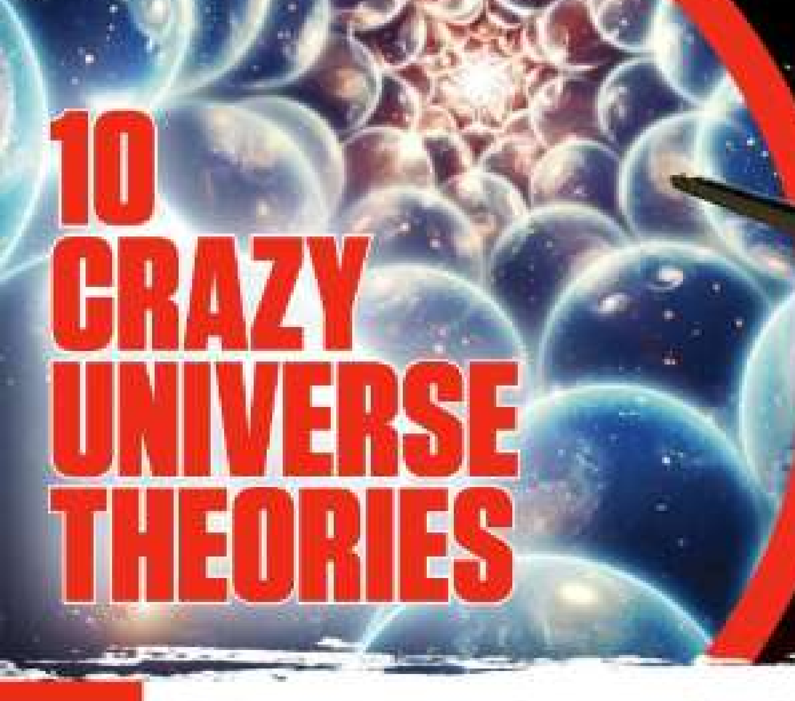

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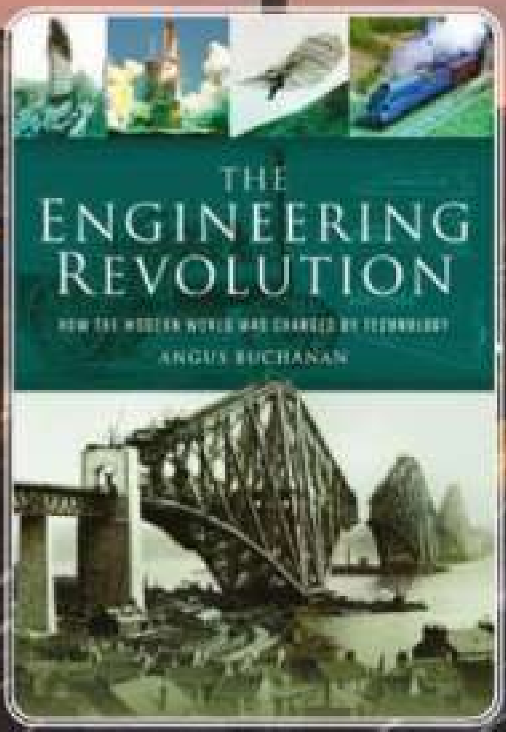
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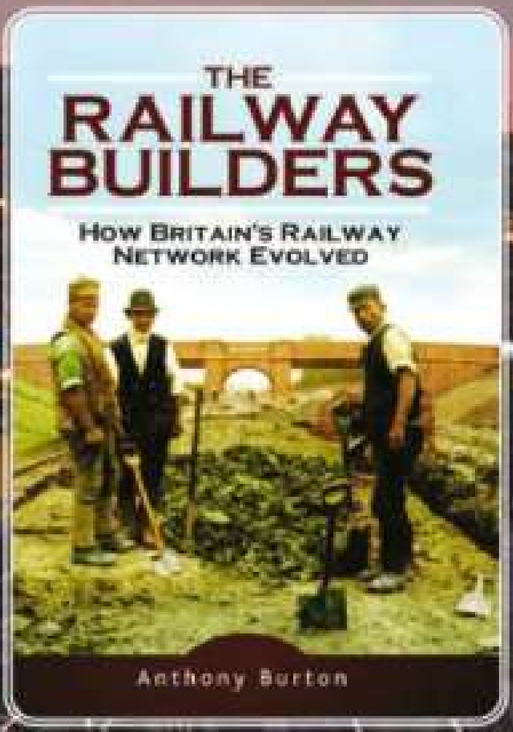
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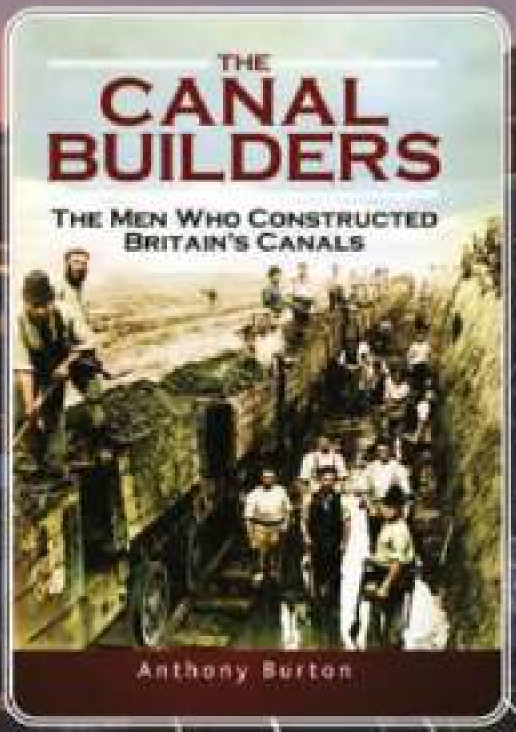
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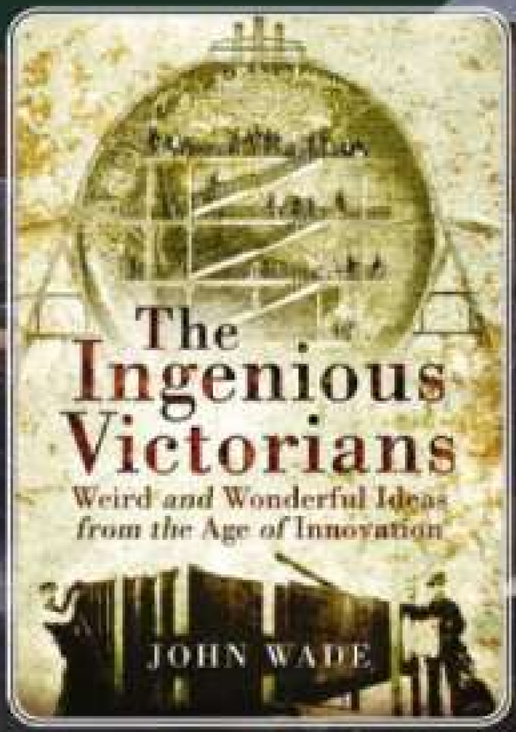
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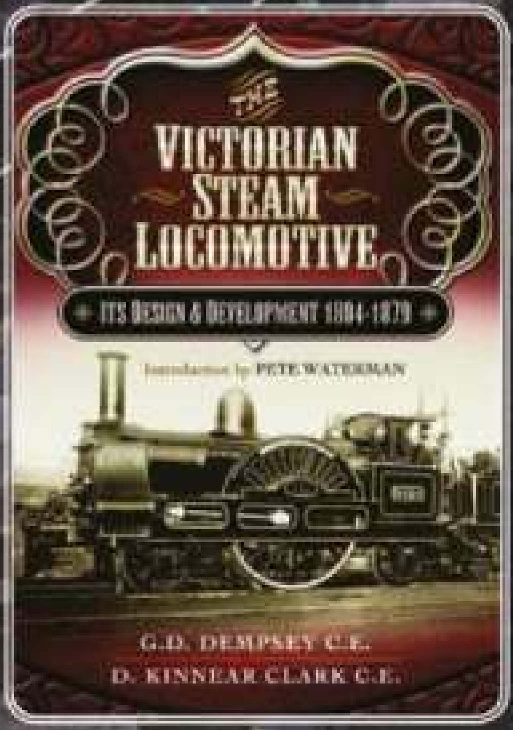
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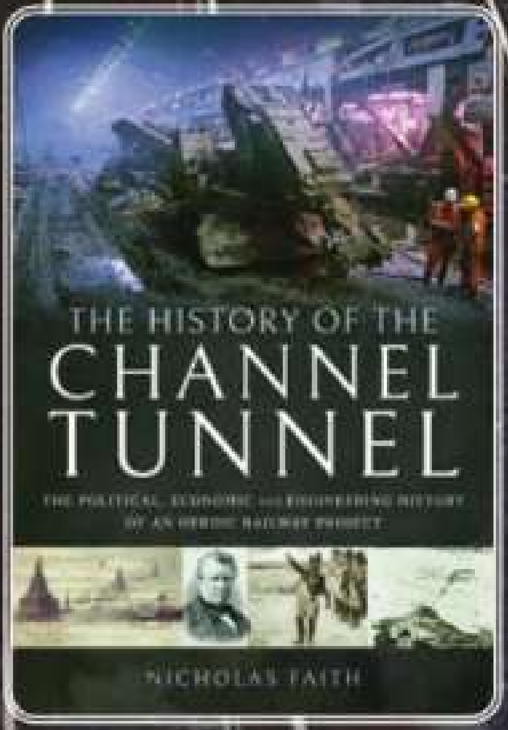
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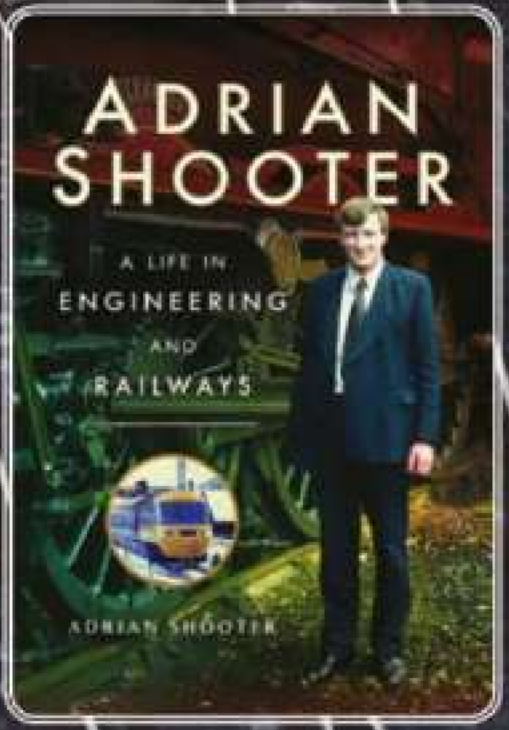
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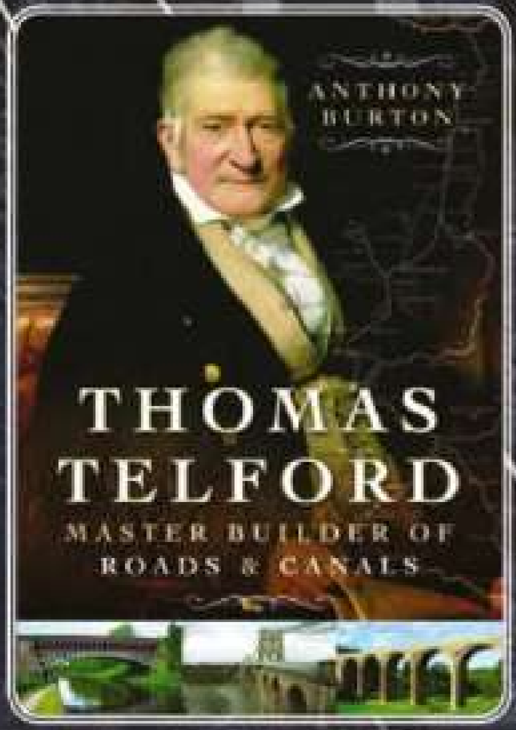
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HOW TO BE A
RALLY DRIVER
How It Works gets muddy at the World Rally Championship in Wales

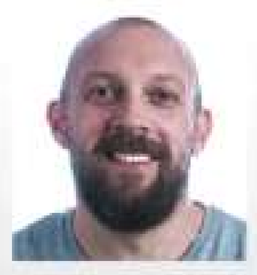
> *"Teams spend millions of pounds to get the most out of their 380-horsepower cars"*
> **How to be a rally car driver, page 22**

Meet the team...

Nikole
Production Editor
Would you wear a skirt that could burst into flames? Turn to page 76 to look back in time at some rather deadly fashion trends.

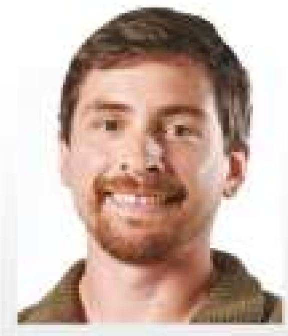
Scott
Staff Writer
It's not just plants that can turn sunlight into food: find out how some animals use photosynthesis on page 66.

Baljeet
Research Editor
The Big Bang is the leading theory for the universe's creation – but not the only one. Explore these odd alternate theories on page 58.



Duncan
Senior Art Editor
Electric vehicles help in the fight against climate change, and e-scooters apply this to compact vehicles. Learn more about them on page 32.

Ailsa
Staff Writer
Could these upcoming gadgets and inventions be the big breakthroughs of 2020? Read more on page 44.



If you've ever driven down an old country road or a lane to a farm, you'll have noticed how much bumpier and difficult to navigate it is, even at low speeds. To charge across this kind of off-road terrain successfully at high speed, around hairpin bends and over steep ramps, takes an exceptionally skilful team and a technologically sophisticated vehicle that costs several times your average Ferrari supercar. This issue, we take a look inside a World Rally Championship car to see how it's capable of tearing through the countryside. We've also spoken to rally driver Jon Armstrong, who tells us what it takes to compete at this level. Enjoy!

Ben Editor

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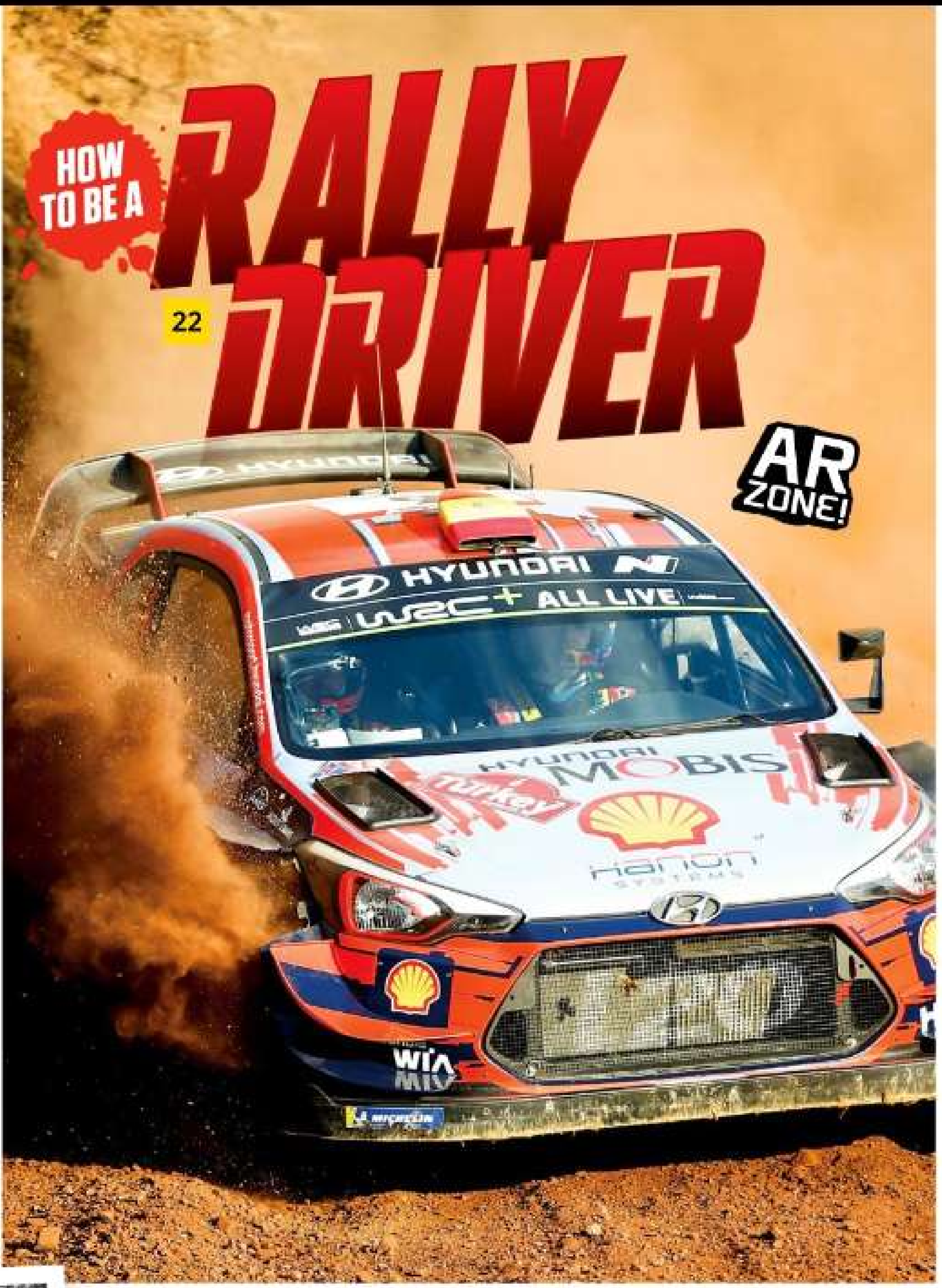

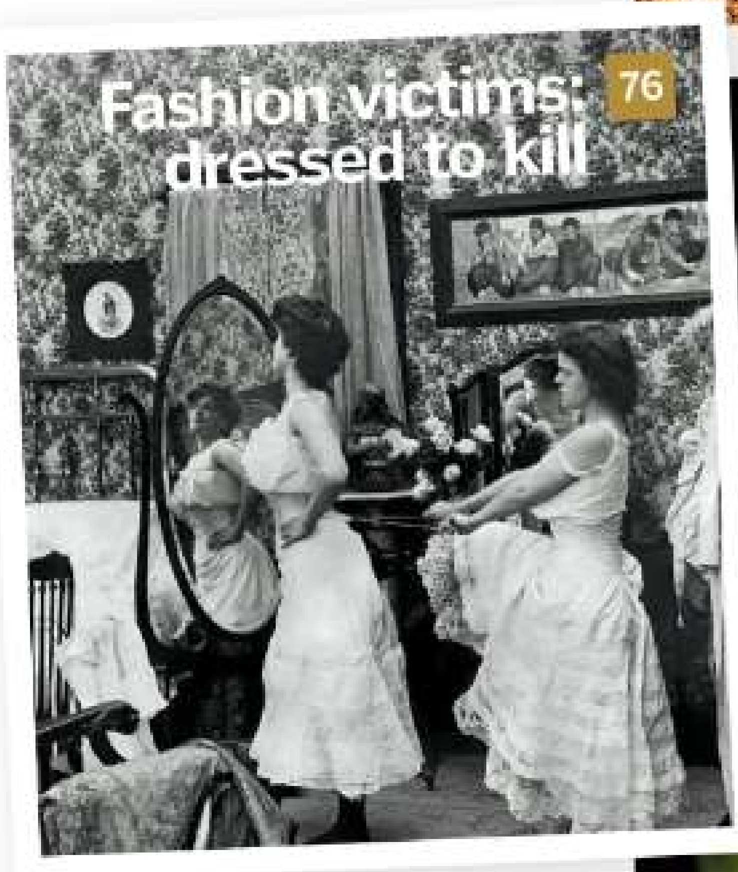
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MEET THIS ISSUE'S EXPERTS…

Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

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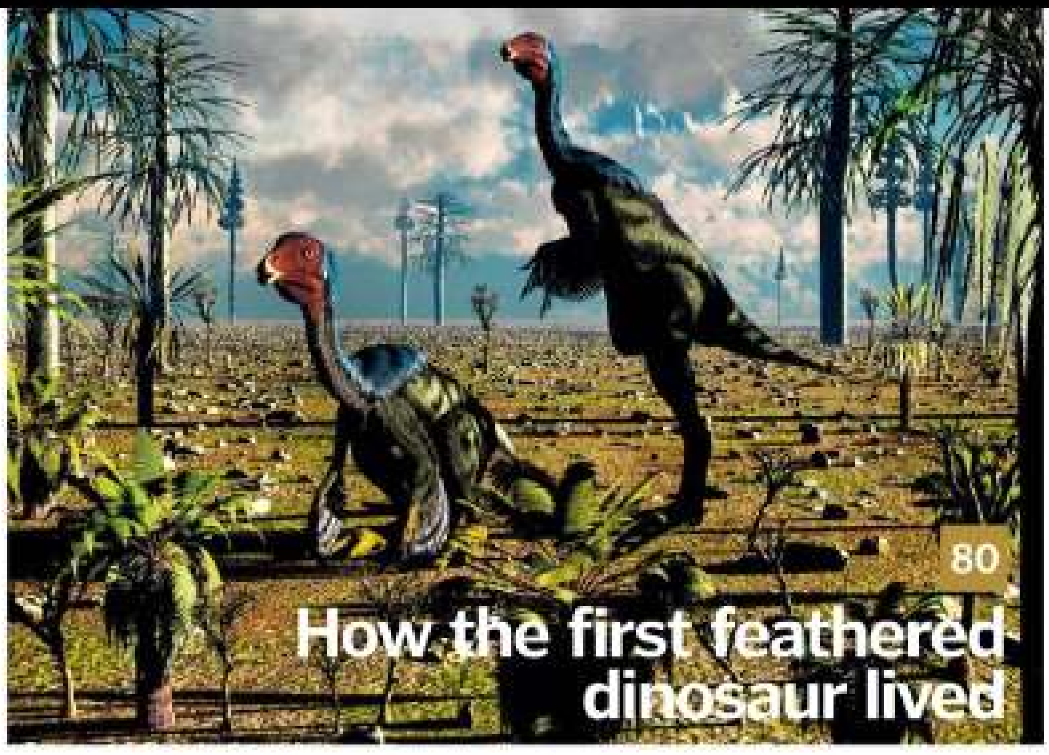

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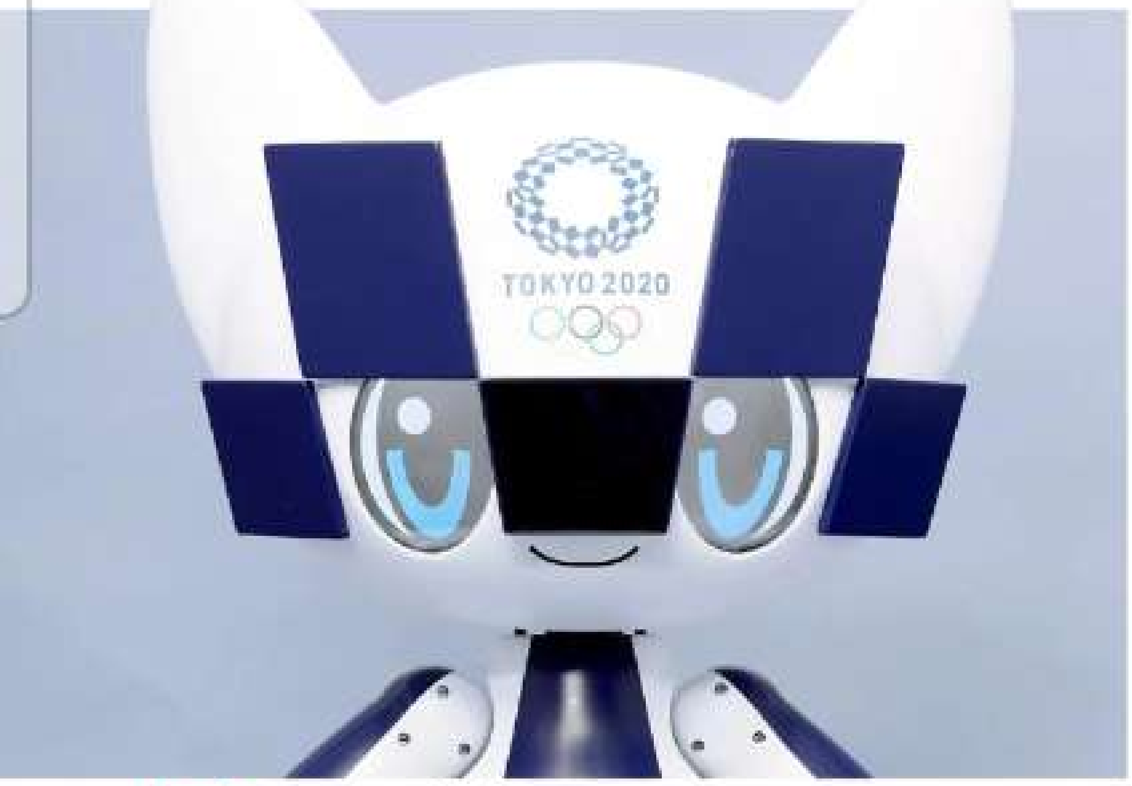

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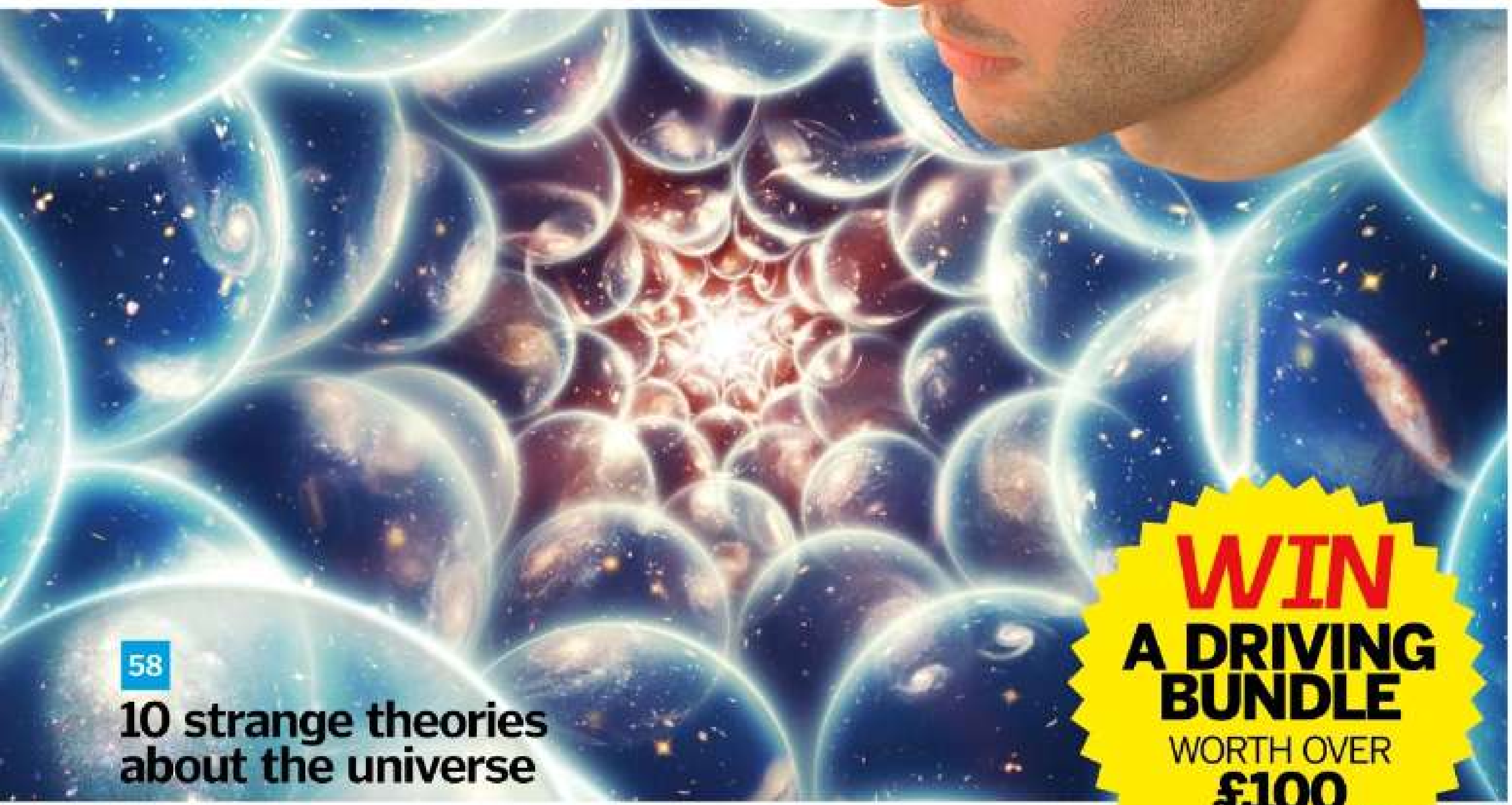

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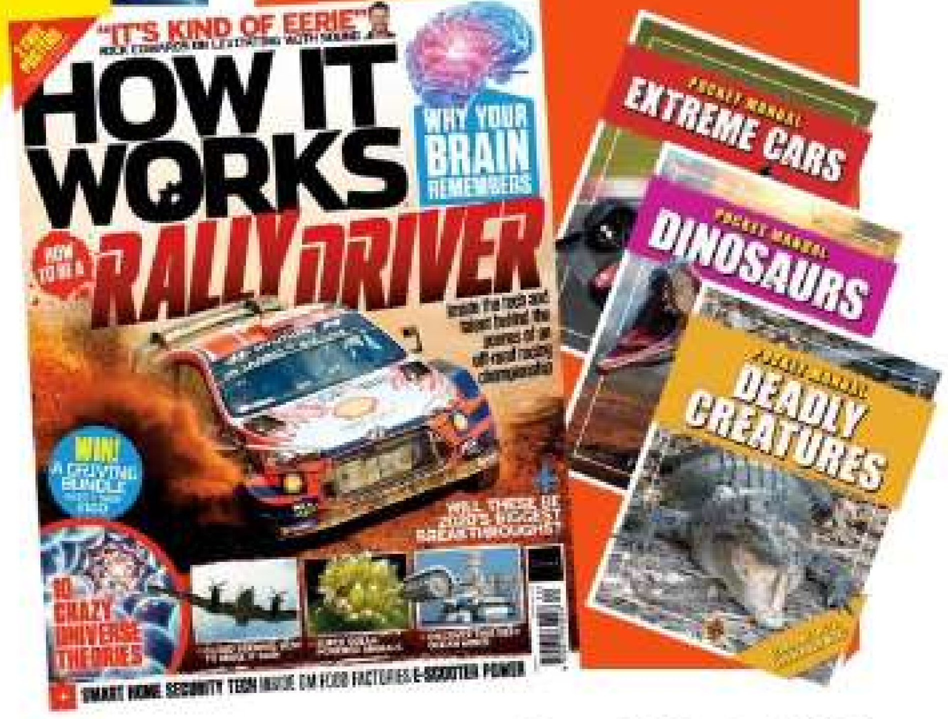


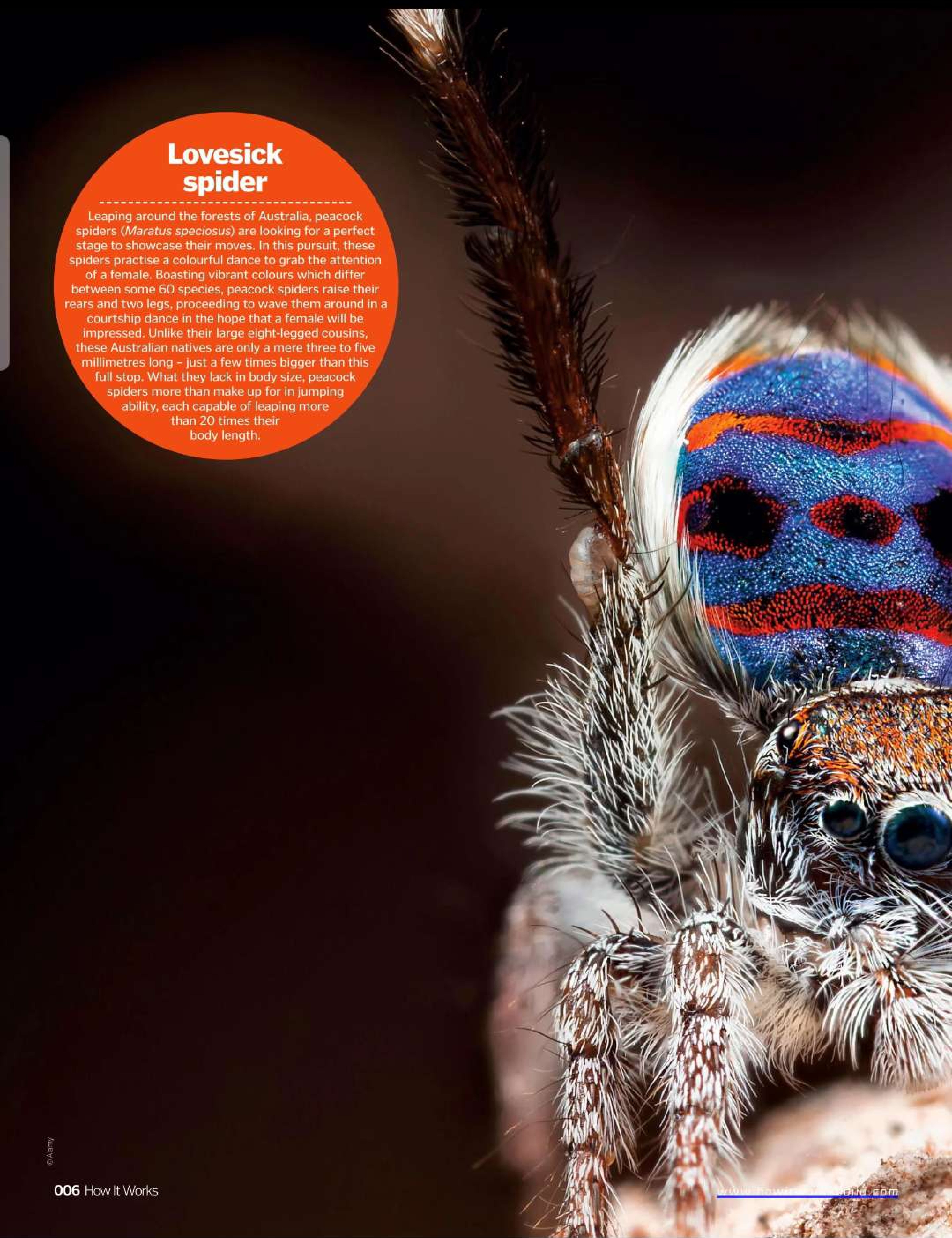
Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

Steve Wright
Steve has worked as an editor on various publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

Felicity Day
Felicity is a qualified solicitor who has turned her hand to freelance writing, specialising in British heritage and history. She particularly loves the Georgian era.

Mike Jennings
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.



Lovesick spider

Leaping around the forests of Australia, peacock spiders (*Maratus speciosus*) are looking for a perfect stage to showcase their moves. In this pursuit, these spiders practise a colourful dance to grab the attention of a female. Boasting vibrant colours which differ between some 60 species, peacock spiders raise their rears and two legs, proceeding to wave them around in a courtship dance in the hope that a female will be impressed. Unlike their large eight-legged cousins, these Australian natives are only a mere three to five millimetres long – just a few times bigger than this full stop. What they lack in body size, peacock spiders more than make up for in jumping ability, each capable of leaping more than 20 times their body length.

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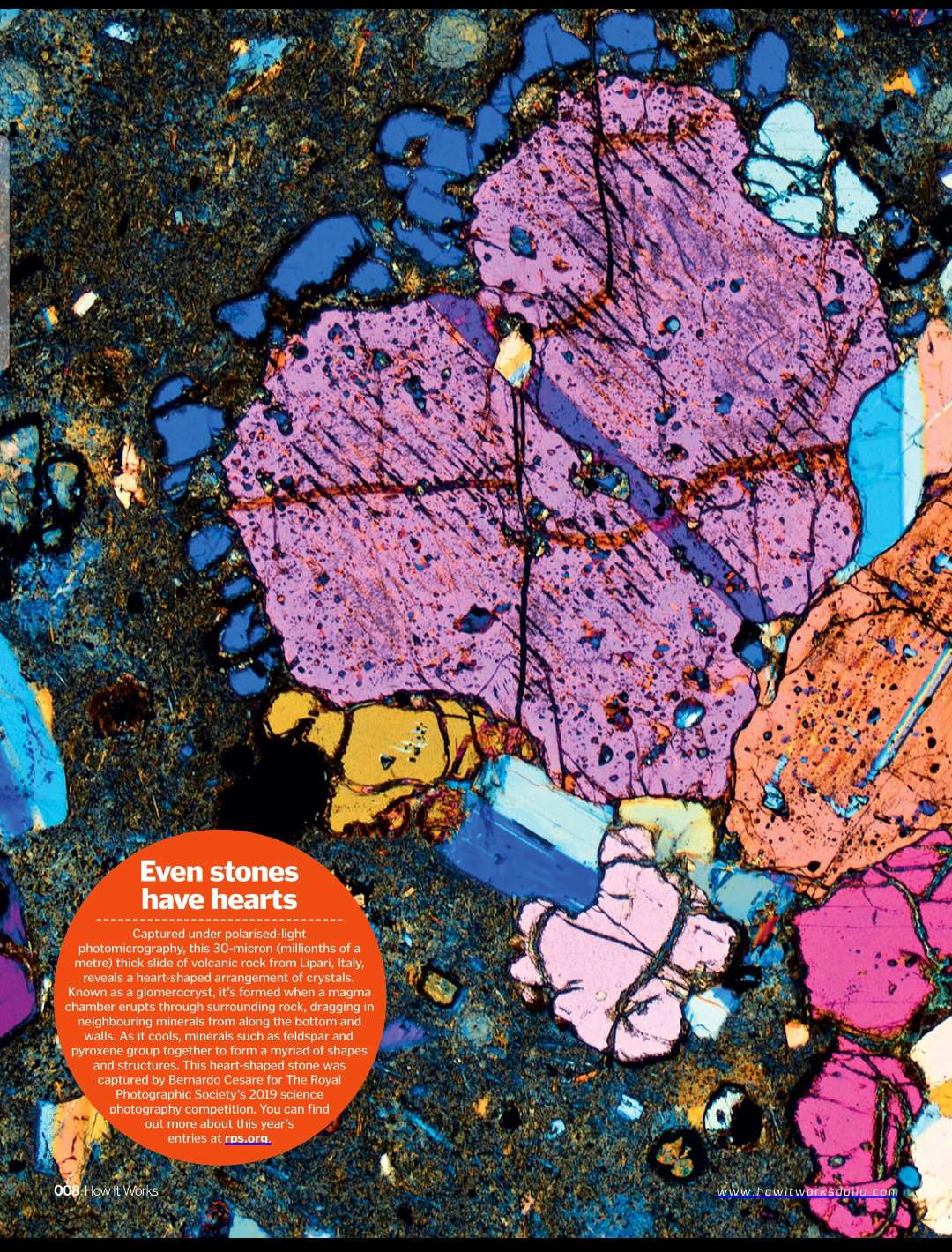
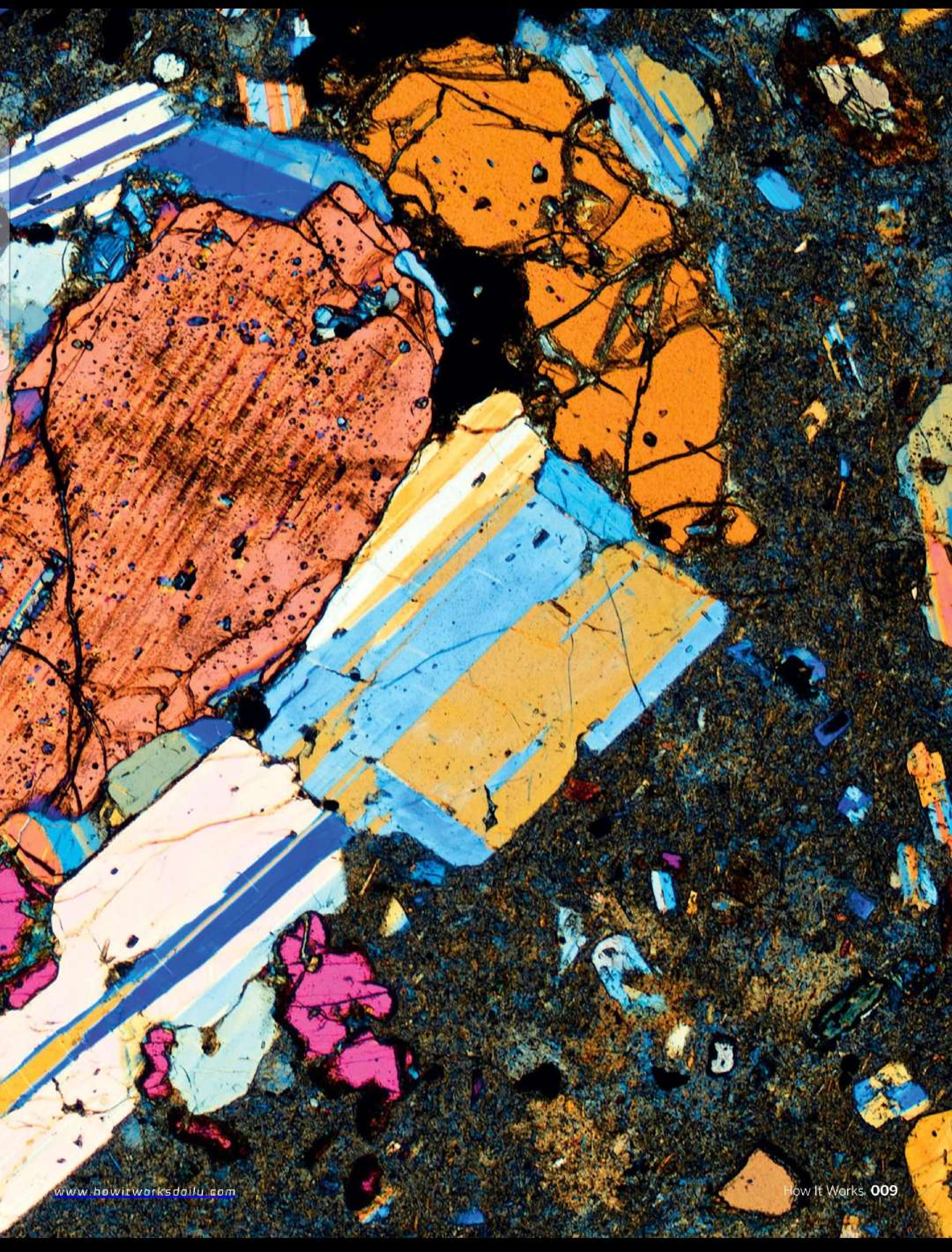


Even stones have hearts

Captured under polarised-light photomicrography, this 30-micron (millionths of a metre) thick slide of volcanic rock from Lipari, Italy, reveals a heart-shaped arrangement of crystals. Known as a glomerocryst, it's formed when a magma chamber erupts through surrounding rock, dragging in neighbouring minerals from along the bottom and walls. As it cools, minerals such as feldspar and pyroxene group together to form a myriad of shapes and structures. This heart-shaped stone was captured by Bernardo Cesare for The Royal Photographic Society's 2019 science photography competition. You can find out more about this year's entries at rps.org.



Cave's spooky lightshow

If you go down to New Zealand's Waitomo caves, you're sure for a glowing surprise. As you sail along the cave's stream, you'll notice that the walls are illuminated by thousands of tiny glow worms (Arachnocampa Luminosa) living on the cavernous ceiling. In a breathtaking display of bioluminescence, the biological chemistry of each worm allows them to radiate blue-green. More of a maggot than a worm, these larvae are not only putting on a show for cave visitors: they're attracting flying food into a curtain of silk threads around their bodies, called snares. People have journeyed to Waitomo to witness the spectacle of the cave's glowing ceiling since the late 1880s.

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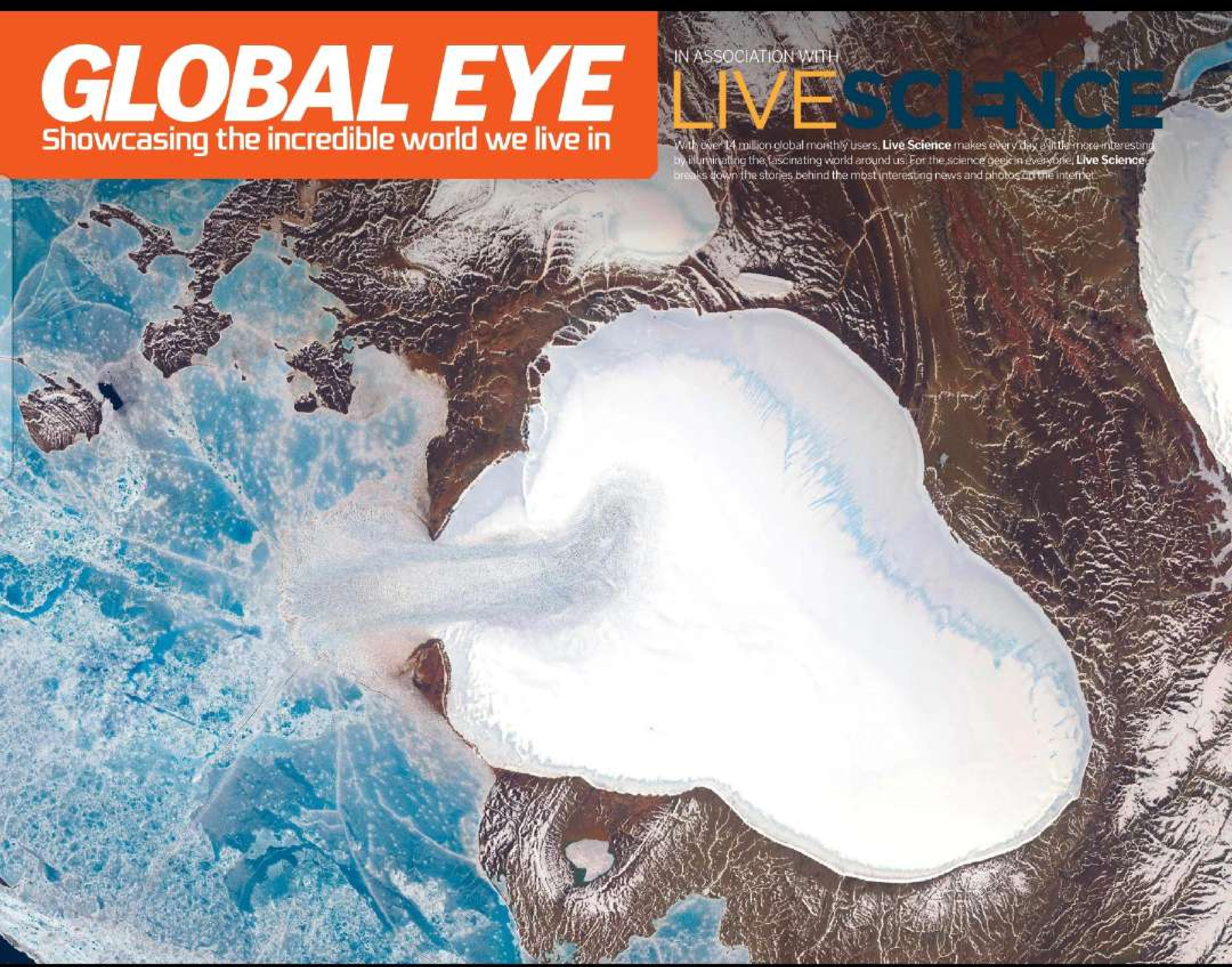

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PLANET EARTH

Scientists witness river of ice emerge

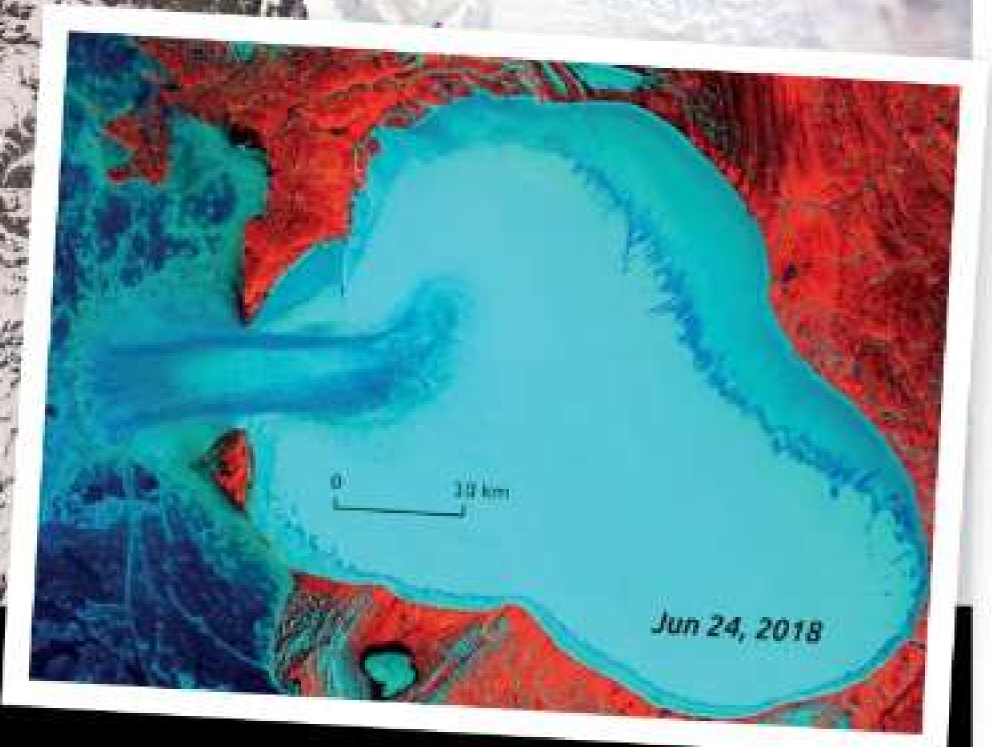
Words by **Rafi Letzter**

For the first time, scientists think they're watching a fast-moving river of ice being born. These so-called ice streams are rapid, long-lasting flows of ice that form in the middle of more static ice formations known as ice sheets. They form in remote parts of the Arctic and Antarctic, and once established can last decades or even centuries. Until now, no one had ever seen one emerge.

In a recent study, a team of glaciologists argues that another shorter-term event that began in 2013 in the Russian Arctic may have sparked the emergence of a long-lasting ice stream. The event, called a glacier surge, is like a frozen flood. A great deal of ice comes loose and bursts out towards the ocean in a rush. "After the initial surge in 2013, the glacier still retains fast flow at around 1.8 kilometres per year," the authors wrote in the new study, published in 2019. That's "an unusually high and long-lasting speed for a glacier surge".

Until recently, researchers thought that glacial surges were routine events, independent of the climate change effects that are melting glaciers around the world. Surges, researchers believed, occur as part of normal growth and shrinking cycles in parts of ice caps that can easily replenish themselves. Ice streams were thought to be separate, unrelated phenomena. But events in recent years, including this event, are challenging the view that ice streams are unrelated to these surges, and that the surges aren't primarily climate-driven, the researchers wrote.

The initial ice surge, at a site known as the Vavilov Ice Cap, has now stretched into a years-long event that has permanently transformed the region, according to the paper. The area is a polar desert, so little new ice is added from one year to the next. And 11 per cent of the ice mass in the region – about 9.5 billion metric tonnes of ice – has already flowed into the ocean, causing the average elevation of the ice cap to drop significantly. In other words, the ice from the surge is not replenishing itself as scientists typically expect following these sorts of events. The key piece of evidence that the surge had



Satellite data shows how ice at the Vavilov Ice Cap flowed in a stream-like pattern towards the ocean on 24 June 2018

© AGU/Geophysical Research Letters/Whyjay Zheng

turned into a stream is the emergence of 'shear margins' around the stream. A surge is just a rapid dumping of ice into the water, but just like liquid water streams, ice streams develop clearly demarcated paths through the landscape. The edges of the new ice stream, as seen from a satellite, are darker and less reflective, the researchers wrote. That's indicative of a long-lasting region of fast-moving ice meeting the slower region around it.

Researchers are still working to understand ice surges, how they relate to ice streams and how climate change drives them. But the Vavilov surge is an important new data point to help piece that story together.

SPACE

NASA's Martian mole is digging again

Words by **Meghan Bartels**

The troubled 'mole' on NASA's InSight Mars lander is moving again, even as scientists working on the robot's seismometer ponder new marsquake mysteries.

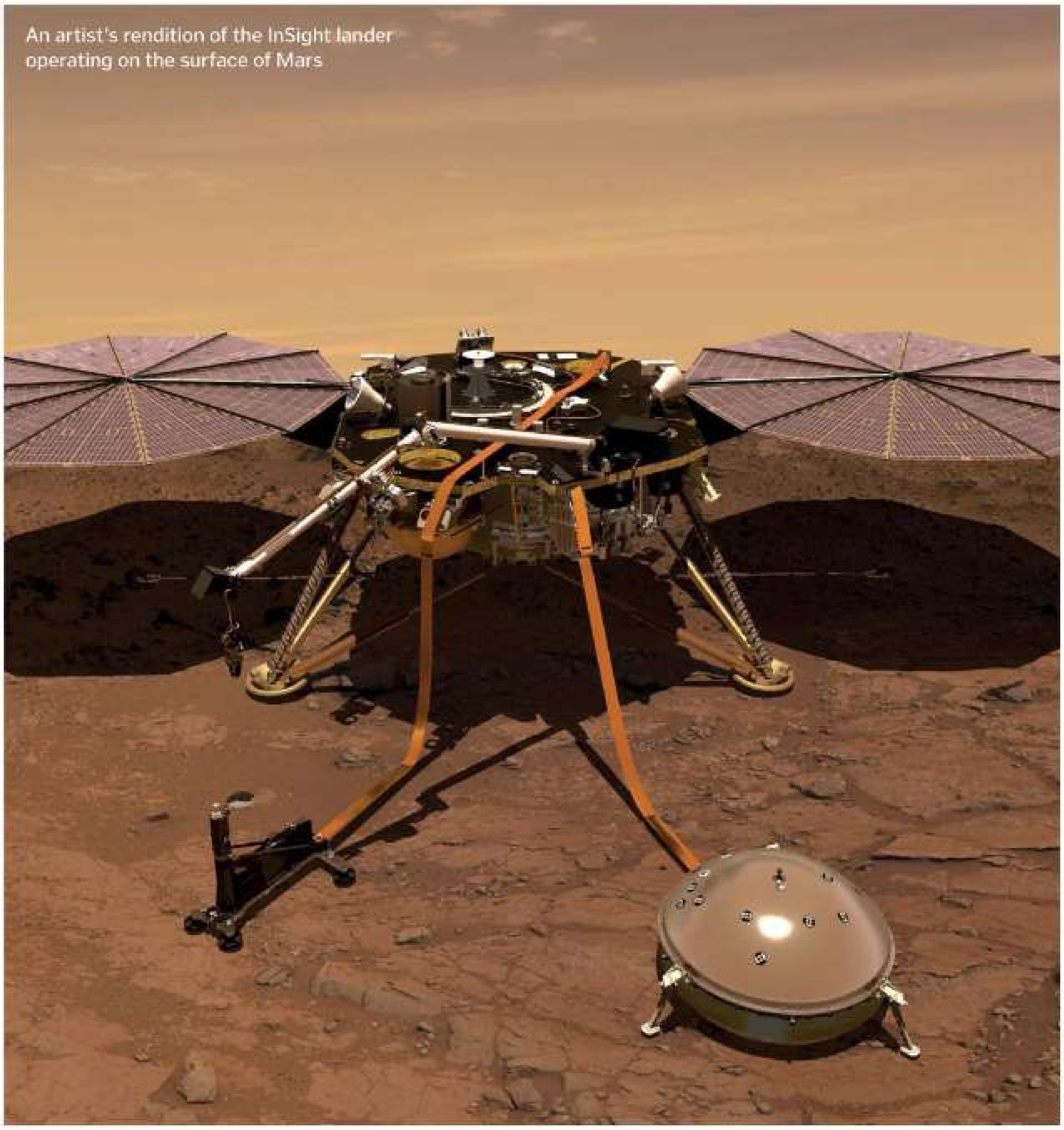
InSight touched down in November 2018 on a quest to understand the interior of the Red Planet. Two of its crucial tools for that task were a burrowing heat probe nicknamed the mole and a super-sensitive seismometer to study motion within the planet.

But soon after spacecraft personnel told the mole to get digging, something went wrong, and scientists and engineers affiliated with the mission have been strategising ways to get the instrument moving ever since.

The team photographed the situation from every angle possible, pondered the likelihood of hidden rocks, evaluated soil characteristics and mimicked the situation with a replica instrument here on Earth. At one point in October, the mole popped out of Mars, as if it had simply had enough of the whole situation.

Most recently the InSight team tried manoeuvring the lander's arm to gently press sideways on the mole. Last November NASA announced that the technique had successfully let the probe dig itself down about 32 millimetres. Then, in mid-December, the agency said that the mole was continuing to burrow properly.

The update did not include details on how far the probe has moved, but a GIF accompanying the tweet suggests that the probe, which measures 400 millimetres in length, dug about 65 millimetres between 7 and 14 December. "More digging to come," the update concluded.



An artist's rendition of the InSight lander operating on the surface of Mars

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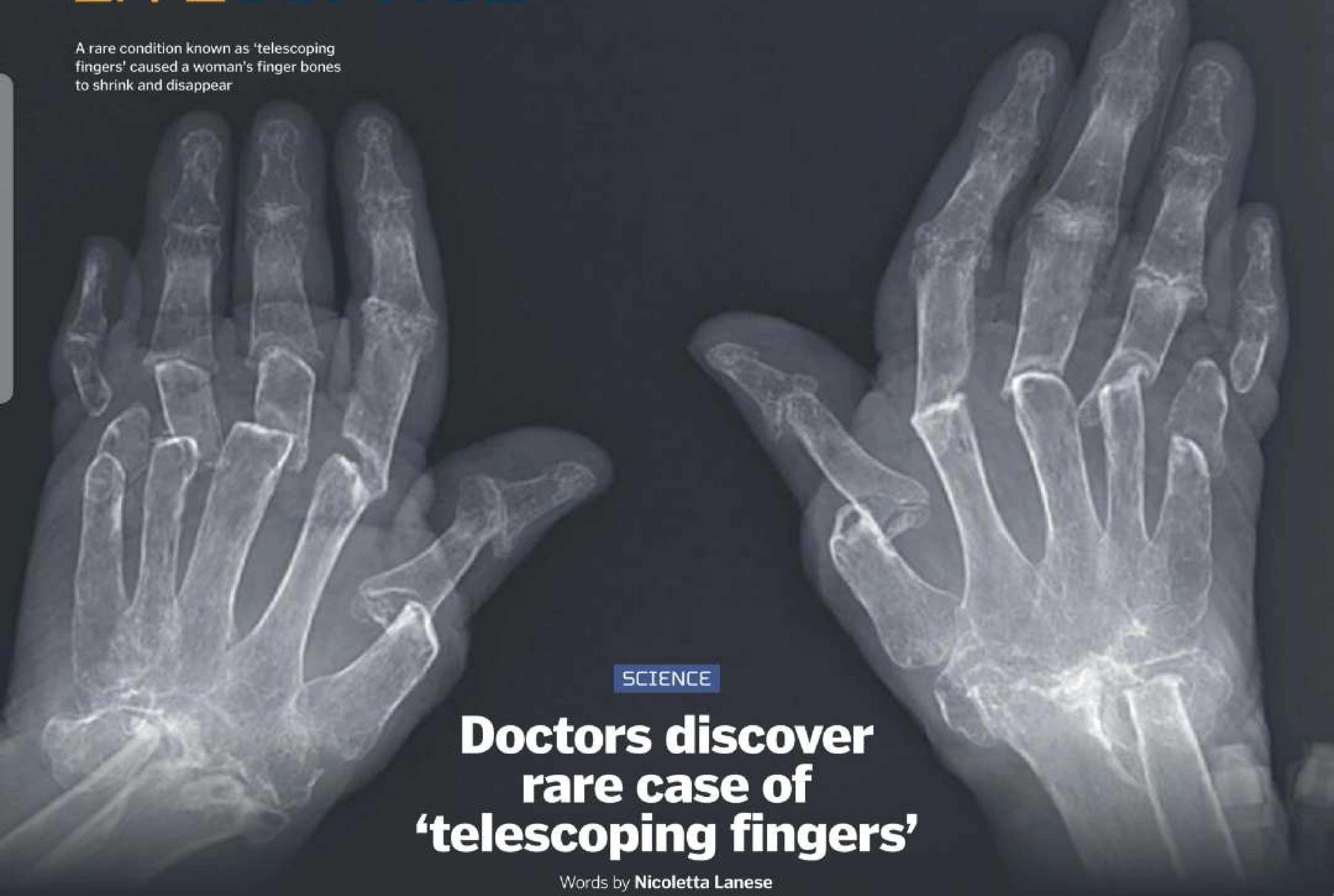

A rare condition known as 'telescoping fingers' caused a woman's finger bones to shrink and disappear

SCIENCE

Doctors discover rare case of 'telescoping fingers'

Words by **Nicoletta Lanese**

A rare condition caused a woman's fingers to scrunch back into her hands as the bones of her hand and wrist steadily disappeared, according to a report of the case. The bone loss caused the 69-year-old woman's fingers to buckle back into her hand like segments of a collapsing telescope, a distinct symptom that explains the unusual condition's nickname, 'telescoping fingers'.

An estimated 3.7 to 6.7 per cent of people with a condition called psoriatic arthritis develop 'telescoping fingers', according to a 2013 report in the journal *Reumatología Clínica*; the condition also occurs in people with rheumatoid arthritis, but even more rarely.

In the recent case, described in a report published last month in *The New England Journal of Medicine*, the woman's hands appeared severely deformed and swollen when she went to a rheumatology clinic in Turkey for treatment. The patient had been diagnosed with rheumatoid arthritis 18 years earlier, and over time her knuckles had grown so swollen that her fingers skewed to one side towards her pinky fingers, her doctors noted. Upon examining the patient's hands, the doctors discovered that the bones of her displaced digits seemed unusually short – far too short for the woman to properly flex her fingers or make a fist.

Radiographs of the patient's wrists and hands revealed the extent of the damage: the bones of the woman's fingers, hand, wrist and lower forearm appeared worn down, as if substantial amounts of tissue had disappeared. The doctors diagnosed the woman with telescoping fingers, medically known as arthritis mutilans, and attributed the tissue loss to a process called osteolysis, which causes bones to be 'reabsorbed' by cells called osteoclasts.

Normally osteoclasts help to sculpt bones from tissue generated by other cells and ensure that our skeleton fits together correctly as we grow, according to *Quantitative Human Physiology*. But when osteoclasts go haywire, the cells can eat up bone that should otherwise stay in place. In people with arthritis, osteoclasts may be prompted to attack bone cells by inflammatory substances present in the tissue.

In the 69-year-old patient, damage inflicted by overactive osteoclasts caused her bones to shrink. While the woman's fingers folded back into her hands, her skin didn't shrink to match, so the excess tissue bunched up in wrinkled folds. By gently pulling on the tips of the woman's fingers, her doctors were able to temporarily stretch the digits to their original lengths.

> "The bone loss caused the 69-year-old woman's fingers to buckle back into her hand"

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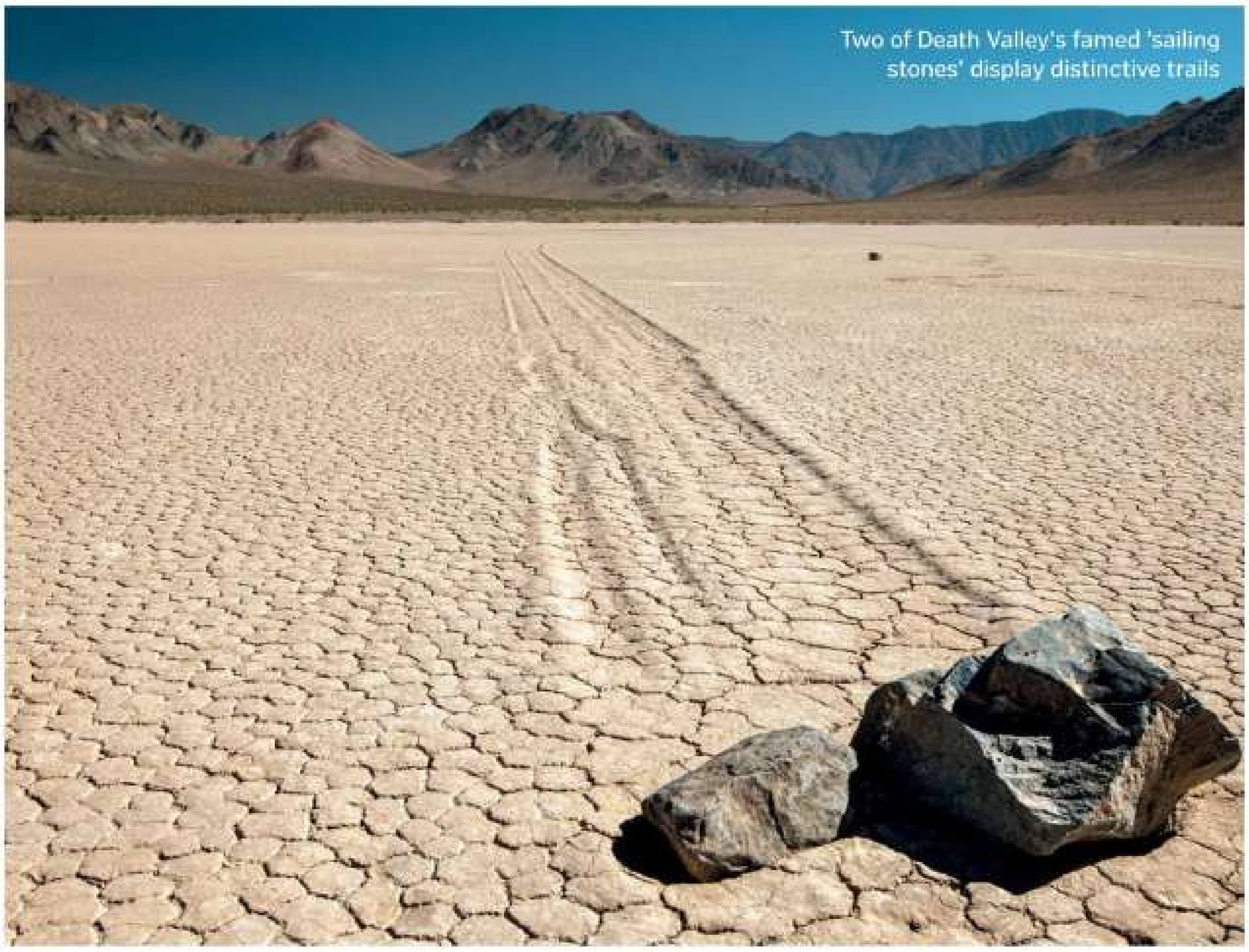
PLANET EARTH

Ancient slab preserves 200 million-year-old mystery

Words by **Mindy Weisberger**



Two of Death Valley's famed 'sailing stones' display distinctive trails

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Rocks that seem to propel themselves across desert landscapes have long mystified and intrigued scientists. Now, researchers have identified tracks of these so-called sailing stones dating back about 200 million years in a rocky slab long prized for the five early dinosaur footprints it preserved.

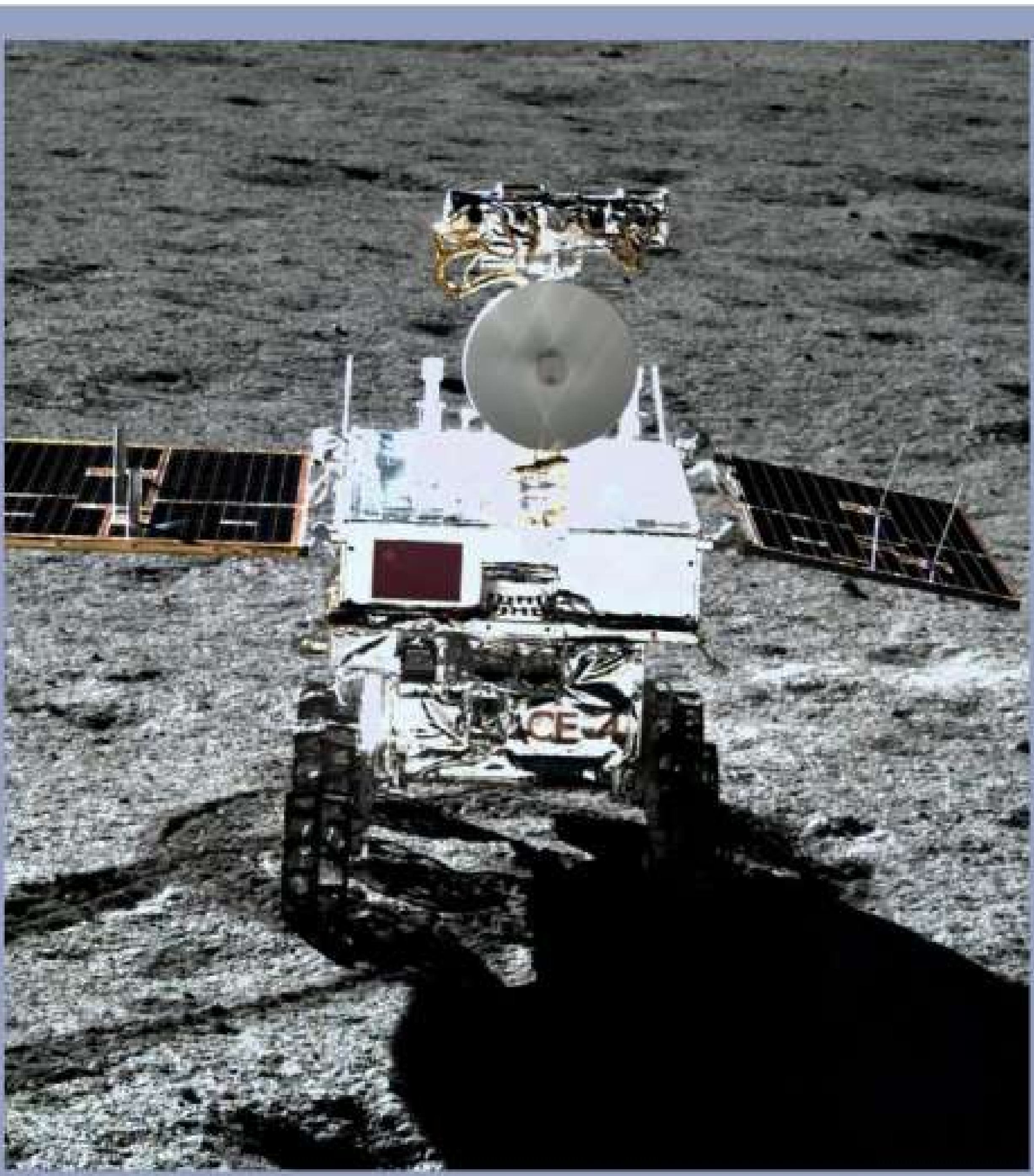
The three-metre sandstone slab of dino prints was discovered more than a century ago, though some of the marks alongside those prints had gone unexamined. Some of the marks – a series of grooves – suggested that a stone once 'sailed' across the surface of this rock, likely buoyed by a slick coating of ice and microbial slime.

Other clues in the stone hinted that the dinosaur and the sailing stone weren't the only ones to leave their marks; pairs of small depressions suggested that a tiny, hopping mammal also scampered across the surface.

The dinosaur tracks on the slab belonged to Anchisaurus, a prosauropod dinosaur, an early ancestor of enormous sauropods that emerged in the late Jurassic period.

The ancient stone slab was excavated from a quarry in Portland, Connecticut, and around 200 million years ago that region of the world was humid and tropical. However, it could have endured a temporary cooling period following explosive volcanic eruptions that spewed masses of sulphur into the atmosphere.

However, there's something else that could have made a rock slick enough to sail: microbial mats. Slimy coatings of microbial goo have created sailing stones in Spain, and similar microbial coatings could also have covered the stone that sailed 200 million years ago.



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China's champion long-duration Moon rover, Yutu-2

SPACE

China's rover breaks Moon work record

Words by **Leonard David**

China's far-side lunar rover Yutu-2 has broken the longevity record for working on the surface of the Moon. China Global Television Network (CGTN) recently reported that the robot rolled by the previous record set by the Soviet Union's Lunokhod 1 rover.

Lunokhod 1 was the first roving remote-controlled robot to land on another world, operating in Mare Imbrium, or the Sea of Rains, starting on 17 November 1970. Lunokhod 1 operations officially ceased about 10.5 months later.

Yutu-2 has been working on the Moon for more than 12 months, since 3 January 2019.

The rover is part of China's Chang'e 4 mission, which also includes a stationary lander. The duo touched down on the floor of the 186-kilometre Von Kármán crater, which lies within the South Pole-Aitken Basin.

In early December 2019, Yutu-2 and the Chang'e 4 lander ended their work for the 12th lunar day, switching to dormant mode for the lunar night, reported the Lunar Exploration and Space Program Center of the China National Space Administration (CNSA). At that time the wheeled rover had chalked up over 345 metres of travel, CNSA officials noted.

SPACE

Huge storm creates mysterious hexagon on Jupiter

Words by **Mike Wall**

NASA's Juno probe discovered a giant new storm swirling near Jupiter's south pole in November 2019, a few weeks after pulling off a dramatic death-dodging manoeuvre.

Juno spied the newfound maelstrom, which is about as wide as Texas, during its 22nd science pass of Jupiter. The storm joins a family of six other cyclones in Jupiter's south polar region, which Juno had spotted on previous passes by the gas giant. Those encounters also revealed nine cyclones near Jupiter's north pole.

The southern tempests are arrayed in a strikingly regular fashion. Previously five of them had formed a pentagon around a central storm, which is as wide as the continental United States. With the new addition, that girdling structure is now a hexagon.

"These cyclones are new weather phenomena that have not been seen or predicted before," Cheng Li, a Juno scientist from the University of California, Berkeley, said in a statement.

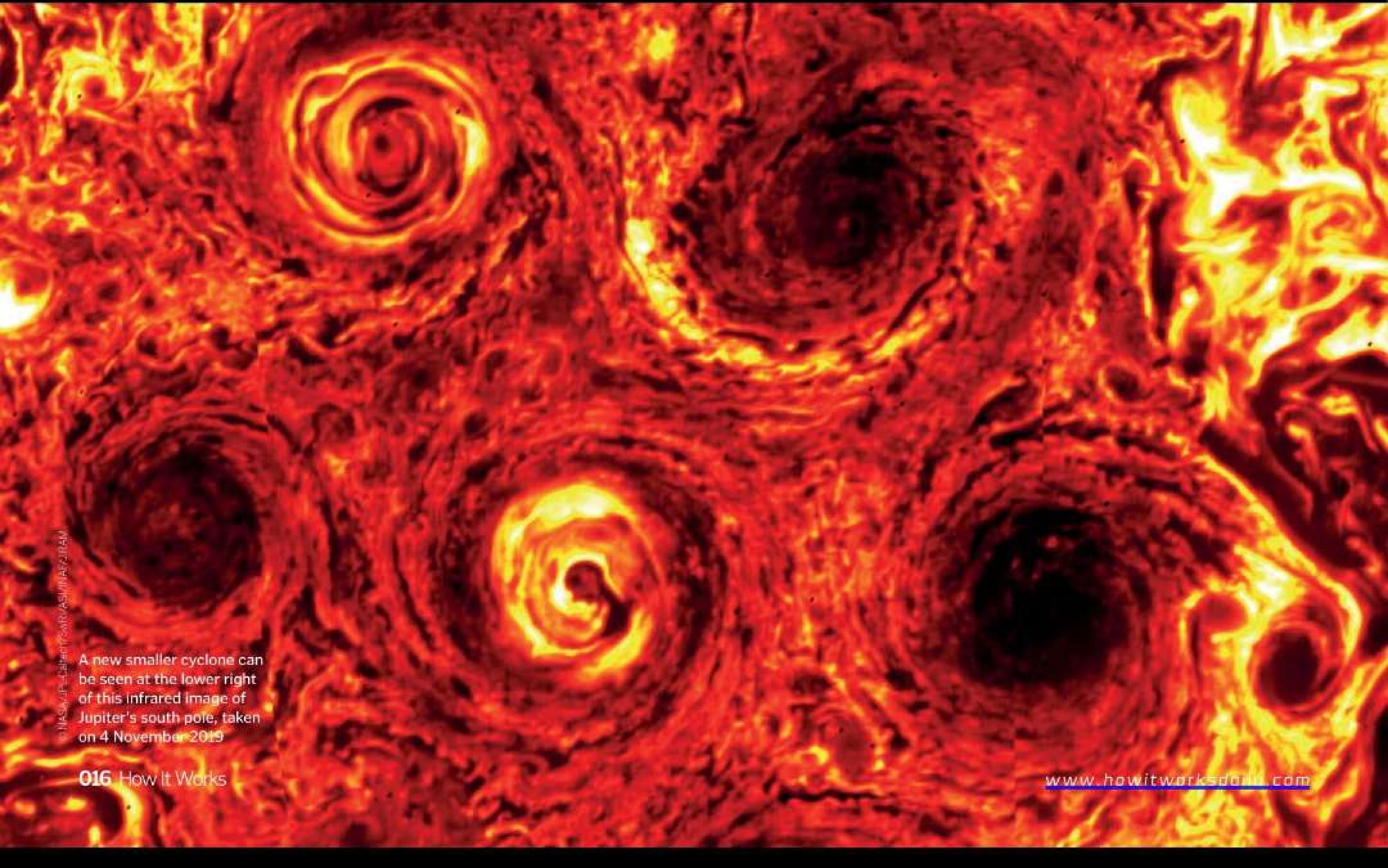
"Nature is revealing new physics regarding fluid motions and how giant planet atmospheres work," he added. "We are beginning to grasp it through observations and computer simulations. Future Juno flybys will help us further refine our understanding by revealing how the cyclones evolve over time."

Juno orbits Jupiter on a highly elliptical path every 53 Earth days, gathering most of its data when it comes closest to the giant planet. But it took some fancy flying to make sure Juno survived the experience. The mission team determined that the probe's trajectory would take Juno into Jupiter's shadow for 12 hours on 3 November, and that likely would've been a death sentence for the solar-powered probe.

"We would've gotten cold. Really, really cold," Juno project scientist Steve Levin of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, said during a press conference at the annual autumn meeting of the American Geophysical Union (AGU), where the team announced the new results.

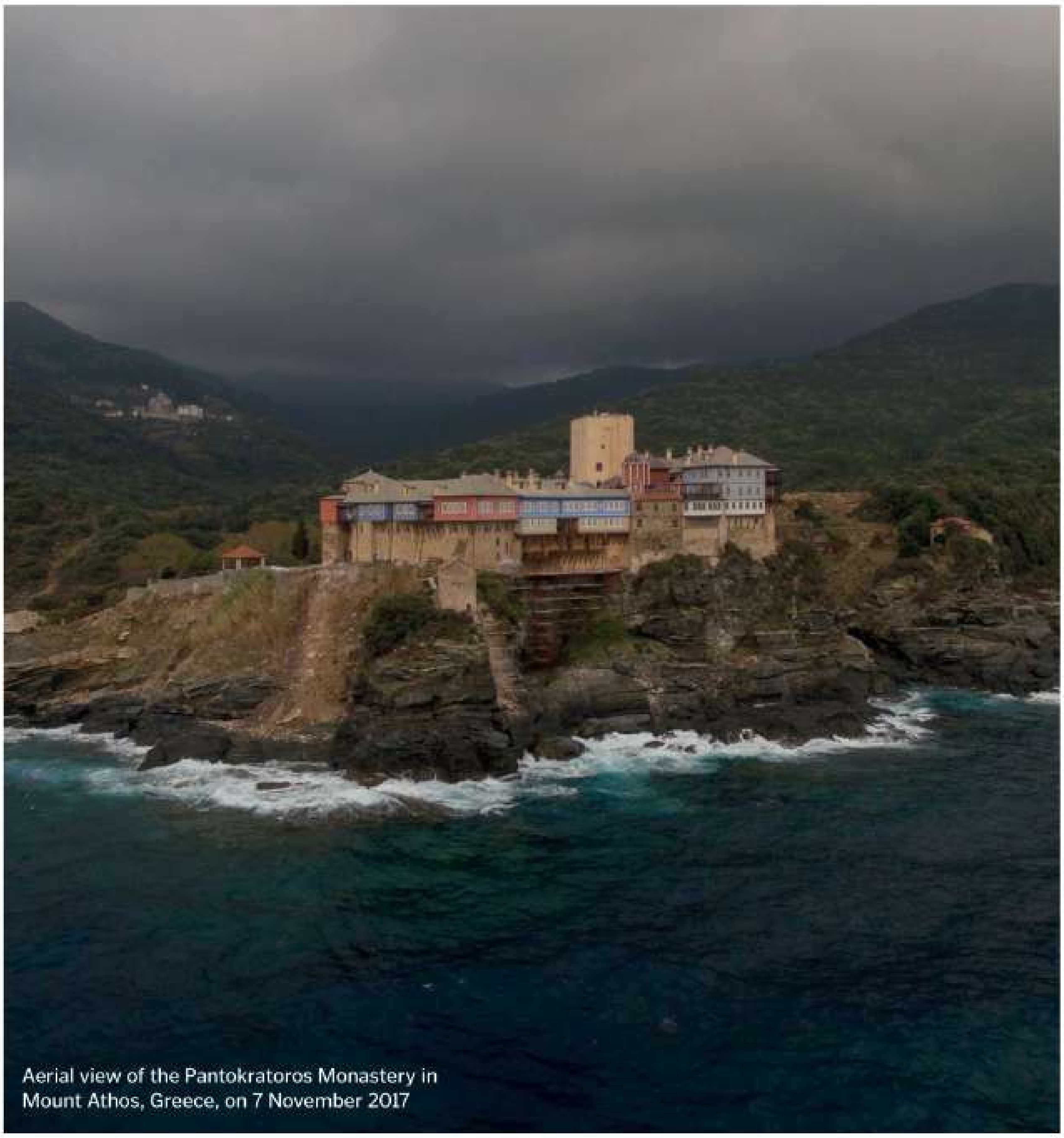
But the navigation team at JPL came up with a solution: 'jumping Jupiter's shadow'. On 30 September, Juno's handlers directed the solar-powered probe to fire its small reaction-control engines in pulses for 10.5 hours. This pushed the probe's path steadily outward and ultimately out of the shadow path altogether, Levin explained.

"Without that manoeuvre, without the creative genius of the folks at JPL on the navigation team, we wouldn't have the beautiful data that we have to show you today," he said.



A new smaller cyclone can be seen at the lower right of this infrared image of Jupiter's south pole, taken on 4 November 2019

© NASA/JPL-Caltech/SwRI/ASI/INAF/JIRAM



Aerial view of the Pantokratoros Monastery in Mount Athos, Greece, on 7 November 2017

© Getty

HISTORY

Old bones in all-male monastery likely female

Words by **Mindy Weisberger**

A so-called all-male 'holy mountain' in northern Greece has hosted Christian monasteries for nearly 2,000 years, with women strictly prohibited. But one woman may have found a home there – at least in death.

During a recent restoration in the Pantokratoros Monastery on Mount Athos, archaeologists unearthed bones under the chapel floor that were smaller than most of the other remains found at the site. In fact, some experts are claiming that these diminutive bones once belonged to a female. "As far as I know, this is the first case that bones belonging to a woman have been discovered on Mount Athos," architect and restorer Phaidon Hadjiantoniou, the project leader for the excavation, told the *Greek Reporter*.

The size and shape of a sacrum, shinbone and forearm, for example, differed from the rest. "While the others were more robust and had clearly belonged to the frames of men, these had measurements that noticeably fell in the range of a female," anthropologist Laura Wynn-Antikas, who examined the remains, told *The Guardian*.

Women are not allowed within 0.5 kilometres of the Mount Athos coast. The ban, which has been in place since the 10th century, was enacted so that the Virgin Mary would represent the sole female presence on the mountain, the BBC reported in 2016. Further tests will be required to determine if the bones from the chapel are truly female, and the remains are currently undergoing analysis at laboratories in Athens, according to the *Greek Reporter*.

HISTORY

First female doctor may never have existed

Words by Yasemin Saplakoglu

Merit-Ptah was an ancient Egyptian physician, often revered as the world's first female doctor. She was thought to live nearly 5,000 years ago, but she likely never existed.

"Merit-Ptah was everywhere," Jakub Kwiecinski, a medical historian at the University of Colorado's School of Medicine, said in a UC statement. "And yet with all these mentions, there was no proof that she really existed." Kwiecinski spent some time searching through literature, looking for any such proof. He traced the first mention of Merit-Ptah to a 1938 book describing the history of women in medicine around the world, written by medical historian, doctor and activist Kate Campbell Hurd-Mead.

In her book she identified the first woman doctor as Merit-Ptah, describing how she lived during the fifth dynasty of Egypt's 'Old Kingdom', or about 2730 BCE.

Inside the tomb of her high priest child was a picture and tablet that described Merit-Ptah as 'the chief physician', Hurd-Mead wrote. However, the burial ground in the Valley of the Kings didn't exist until Egypt's New Kingdom, around 1,000 years after Merit-Ptah was thought to have lived. What's more, though "Merit-Ptah as a name existed in the Old Kingdom," there is no record of that name linked to a physician in any list of ancient Egyptian healers, Kwiecinski said.

© Alamy

Merit-Ptah is often cited as the first woman doctor, but new findings suggest she never existed

ANIMALS

Giant panda babies are being born 'undercooked'

Words by **Rafi Letzter**

A newborn panda cub in an incubator at Chongqing Zoo, China, on 23 June 2019

© Getty

Giant panda babies are born weirdly tiny and underdeveloped. No one knows why, and the major theory just turned out to be wrong. Carnivorans – an order of mammals that includes all bears, dogs, cats, raccoons, weasels and seals, among other species – tend to enter the world small, weak, hairless and blind, according to a recent study. Bears in particular tend to give birth to unusually small cubs.

Some researchers suspect that this oddity has to do with hibernation. At some point bears started cutting short their pregnancies to avoid gestating while they hibernate, and now that trait is baked into every bear species – even pandas, which don't hibernate. That theory has a big problem though: pandas are born exceptionally tiny and underdeveloped, even for bears. And other bears, including species that do hibernate, are born with robust, mature skeletons. Pink, floppy panda babies are the exception. "They're basically undercooked," Peishu Li, the lead study author, said in a statement.

Panda babies are bizarrely tiny. At birth the cubs weigh just about 100 grams, which means that panda mothers are 900-times larger than their babies. Only a handful of other animals, including kangaroos and echidnas, have similar weight differences at birth. Still, it seemed possible that this was part of a universal bear story; polar bear mothers are 400 times the weight of their newborns.

In the 1980s, the first panda couple at the Smithsonian National Zoo in Washington, DC gave birth to five cubs, all of which died soon after birth. Li and her co-author, Duke biology professor Kathleen Smith, got their hands on two of those preserved cubs. The researchers used a CT scanner to build 3D models of the unfortunate critters' skeletons. They also scanned newborn grizzlies, sloth bears, polar bears, dogs, a fox and other animals. Comparing all the skeletons, Li and Smith found that pandas appeared to have uniquely underdeveloped bones at birth. "That would be like a 28-week human foetus," Smith said in the statement. But for now, no one knows why.

SPACE

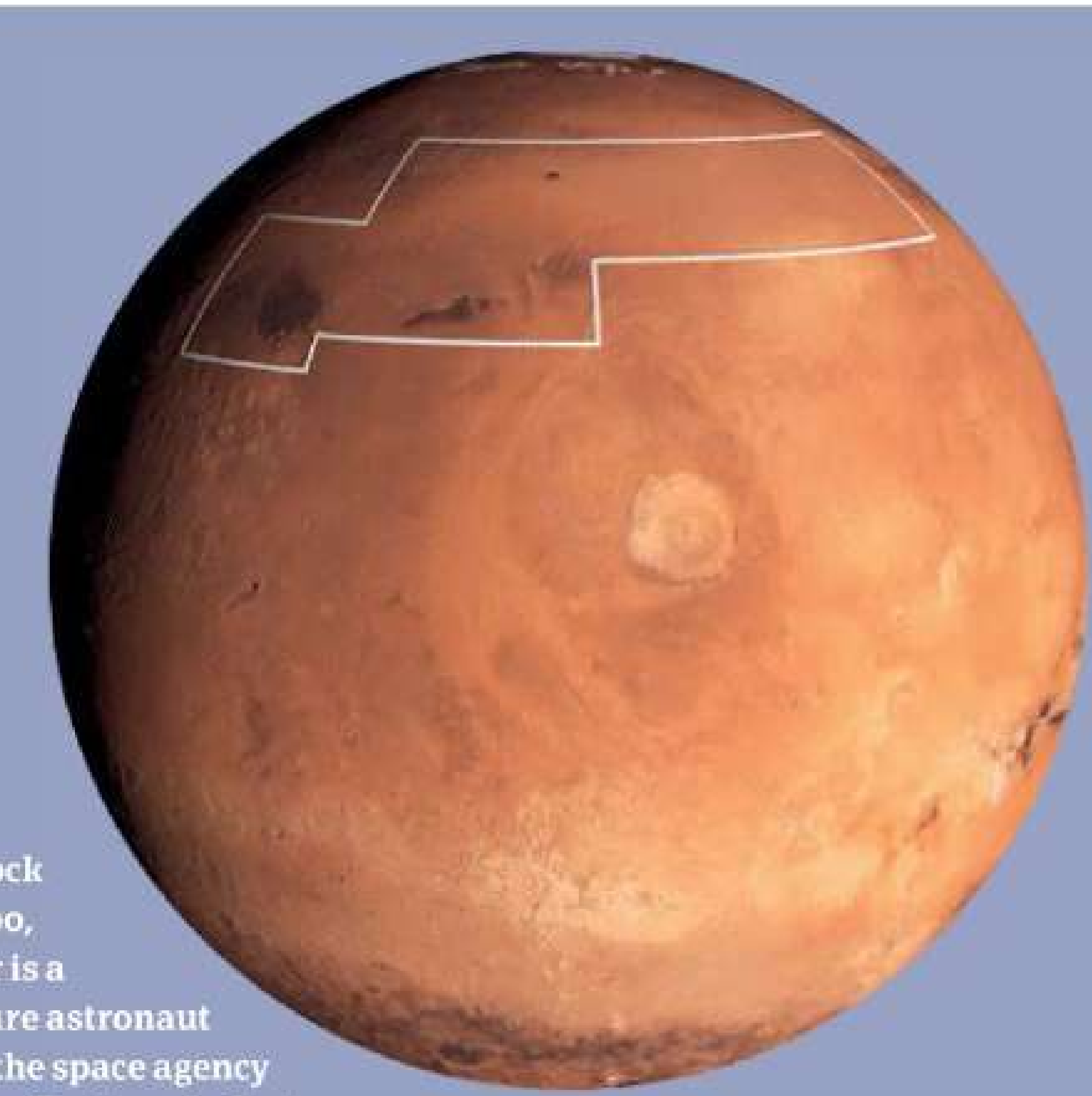
Nasa's 'treasure map' reveals potential human landing site

Words by **Elizabeth Howell**

NASA's wish to follow the water on Mars just got a helping hand. Scientists have released a new global map showing water ice that is as little as 2.5 centimetres below the Red Planet's surface. With data in hand, the research team located at least one promising landing spot for future astronaut missions: a big zone in the northern hemisphere's Arcadia Planitia. This area has a lot of water ice close to the surface and is in the ideal location for a human Mars mission because it is in a temperate, mid-latitude region with plenty of sunlight, the research team wrote in a new study describing the findings.

"You wouldn't need a backhoe to dig up this ice. You could use a shovel," lead author Sylvain Piqueux, who studies planetary surfaces at NASA's Jet Propulsion Laboratory in California, said in a statement. "We're continuing to collect data on buried ice on Mars, zeroing in on the best places for astronauts to land."

Further study of the 'treasure map' could unlock more landing locations too, according to NASA. Water is a precious resource for future astronaut missions to Mars, where the space agency wants to land in the 2030s. The hope is that instead of hauling all of the water astronauts will need from Earth to the Red Planet, astronauts could get their drinking water and the components of water for rocket fuel from Mars itself.



This area of the Red Planet is where NASA spacecraft have found near-surface water ice that would be easy for astronauts to dig up

© NASA/JPL-Caltech

PLANET EARTH

Buried diamonds could explain earthquakes

Words by **Mindy Weisberger**

Deep under Earth's surface, earthquakes rumble in the mantle's transition zone, the area that divides the upper mantle from the lower. Liquid in the mantle is thought to play a part in driving those deep earthquakes, but until now, no smoking gun could prove that fluid was present at those depths.

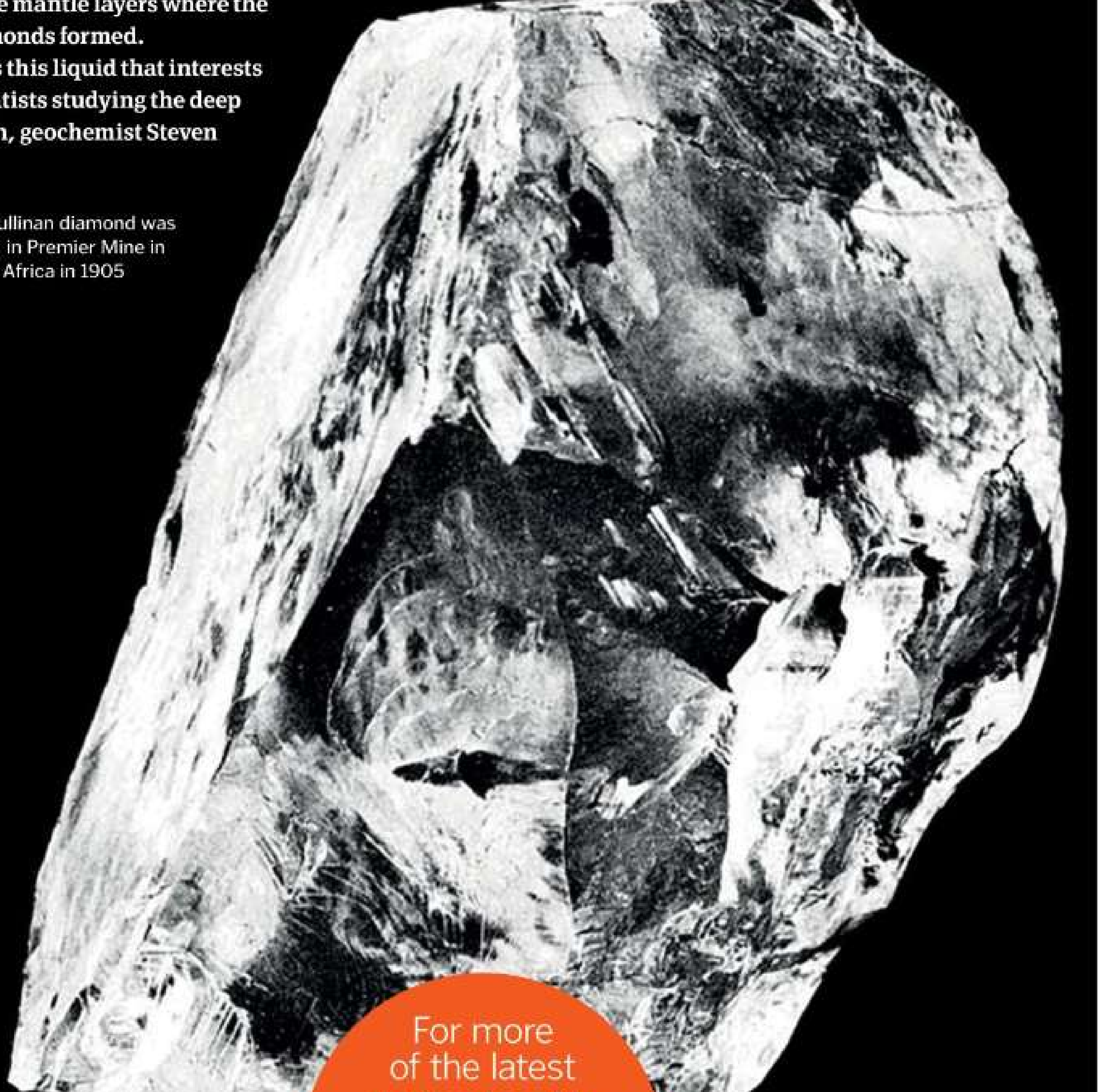
Now, scientists think they may have found evidence of fluid in an unlikely place: inside superdeep diamonds.

While most diamonds crystallise at depths of 140 to 200 kilometres, superdeep diamonds are found as far as 600 to 800 kilometres below the surface. Inside these gems forged at depth are tiny flaws, or inclusions, made by fluids. These flaws reveal that liquid is likely flowing in the mantle layers where the diamonds formed.

It's this liquid that interests scientists studying the deep Earth, geochemist Steven Shirey, a senior research scientist at the Carnegie Institution for Science in Washington, DC, told **Live Science.** That's because the location and movement of these fluids might be the key to understanding deep earthquakes, Shirey said.

In new research, Shirey and his colleagues modelled the movement of fluid at depth using information about the spots where these diamonds formed in the mantle.

In creating these models, the scientists are hoping to connect the dots among fluid movement into the deep mantle, diamond formation "and the physical rupture properties of the rocks in that region" of the mantle's transition zone, Shirey said.



The Cullinan diamond was mined in Premier Mine in South Africa in 1905

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WISH LIST

The latest **driving** tech

Hudly wireless

■ Price: $349 (approx £270)
www.gethudly.com

Staying focused on the road while glancing at your phone or sat nav for directions can sometimes be a distraction. That's why Hudly has created its transparent heads-up display to keep your journey information right in your sightline. Paired wirelessly with your smartphone, this 6.2-inch display allows you to view the road and its vibrant directions simultaneously. Also equipped with light sensors, this heads-up display will automatically adapt its visibility to suit your environment.

© HUDLY

Roav VIVA

■ Price: £45.99 / $59.99
www.anker.com

Bring Alexa along for the ride with this plug-in speaker from Anker. Paired with your smartphone, VIVA can make calls, stream music and provide audio navigation with simple voice commands. Plugged straight into your vehicle's power outlet, this travel-sized companion comes equipped with two USB ports so you and your passengers can charge smart devices on the go.

ROAV
VoltageBoost™
PowerIQ™

© Anker

© nonda

ZUS Smart Tire Safety Monitor

■ Price: $159.98 (approx £125)
www.nonda.co

Keeping your tyres at the correct pressure is imperative to not only staying safe on the roads, but to maintain optimal fuel consumption. With the ZUS smart safety monitors by nonda, you receive real-time alerts if your tyres are leaking air or need a refill. Taking only minutes to install, these high-tech dust caps simply screw on each tyre and give you feedback on how each tyre is performing, recording a detailed history of pressure changes over time.

© GOFAR

GOFAR

■ Price: **$149 AUD (approx £80 / $105)**
www.gofar.co

Open a window into your vehicle's health with GOFAR. By simply plugging the GOFAR adapter into your car's computer, receive real-time information about any mechanical problems or performance information straight to your smartphone. In the same way a Formula 1 driver monitors their fuel efficiency on the track, the GOFAR Ray keeps you up to date on how you consume fuel with the simple dashboard light array. If you're hitting the gas too hard, the GOFAR Ray will illuminate red to let you know you're wasting fuel and green when you're driving optimally.

Jabra
VOICE
VOL-
MUTE
VOL+
© Jabra

Automatic™ connected car assistant

■ Price: **From $99.99 (approx £75)**
www.automatic.com

If you want to get to know your car inside out, then the Automatic™ connected car assistant is the perfect addition to your vehicle. By simply plugging the compact diagnostic device into the vehicle, a whole host of information about your car is available at your fingertips. Using the Automatic™ app, this driving assistant can give detailed diagnostics about maintenance issues and performance alongside crash alerts, your vehicle's real-time location and roadside assistance.

Jabra Freeway

■ Price: **£84.99 / $99.99**
www.jabra.co.uk

If your car isn't Bluetooth connected, then Jabra Freeway is a great gadget to listen to high-quality sound and answer and make calls at the touch of a button or through voice activation. With three built-in speakers, Freeway offers impressive surround sound. However, if you prefer your vehicle's speakers, the built-in FM transmitter will connect your smartphone straight to the car's internal sound system. Equipped with a motion sensor, Freeway will always sense when you get into the car and automatically connect to your smartphone.

Family Car
Vehicle Recall Issued
Roadside Assistance
© Automatic™

APPS & GAMES

Petrol Prices

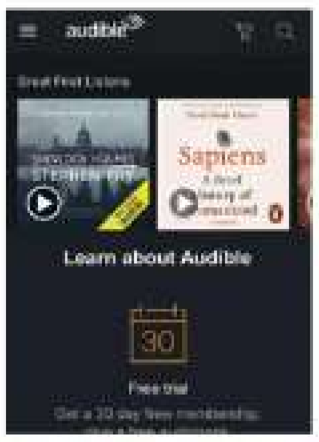
■ Developer: **PetrolPrices.com**
■ Price: **Free / Google Play / App Store**

Don't get caught short with an empty fuel tank on the road with this petrol refuelling station location app, which also ensures you get the best prices in your area.

Audible

■ Developer: **Audible**
■ Price: **£7.99 per month / Google Play / App Store**

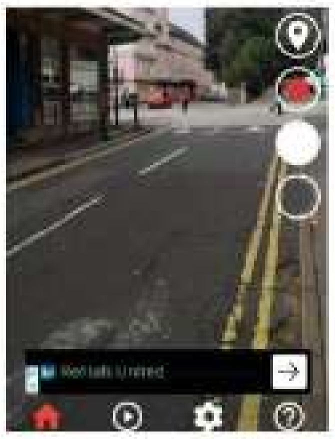
Does reading a book on a long journey make you feel car sick? If so, then Audible offers the world's largest selection of audiobooks and entertainment for you to enjoy.



Smart Dash Cam

■ Developer: **IPCamSoft.com**
■ Price: **Free / Google Play / App Store**

Turn your smartphone into a dash camera to capture your journey and any noteworthy moments, with this easy-to-use app. Simply download, fix your phone a mount, then go.



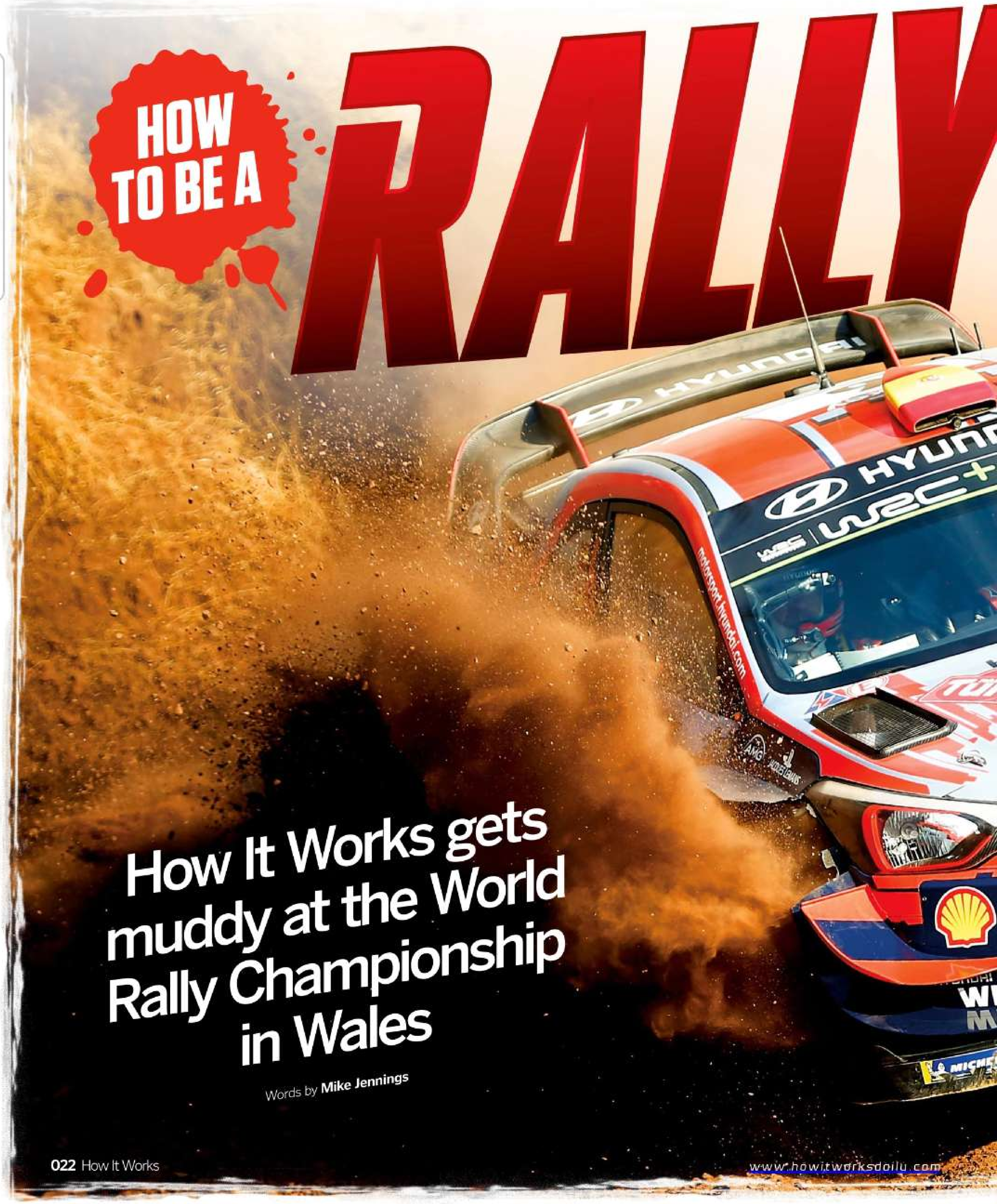
Sign Bingo

■ Developer: **Timothy McLenegan**
■ Price: **Free / App Store**

Keep the whole family entertained during any road trip with this fun bingo app. Be the first to shout "bingo" when you spot all the signs on your bingo sheet. Just make sure the driver isn't playing too.

MENU
NEW GAME
SIGN BINGO

HOW TO BE A RALLY



How It Works gets muddy at the World Rally Championship in Wales

Words by **Mike Jennings**

DRIVER

ALL LIVE
HYUNDAI MOBIS
hanon SYSTEMS
HYUNDAI STEEL

Rally cars really do make a splash on track

Terrain varies massively between each rally stage

No motorsport is as exciting and as adventurous as rally, where drivers tackle remote, rugged terrain in million-pound cars that hit 0-60mph in less than three seconds. It's popular across the world, and no matter where you are the concept is the same: drivers and co-drivers have to complete tough, challenging sections of road in the fastest time possible – and keep their cars in one piece so they can tackle the public roads in between their timed runs.

Drivers are joined by co-drivers, who call out instructions during the stage. It's a tough gig, bellowing notes at more than 100 miles per hour, but it's vital – if a driver has accurate notes, they can attack the road as quickly as possible. Rallying isn't just a partnership between driver and co-driver though – like other motorsports, it's a team game. Rally cars are maintained by teams of expert mechanics at a central service park. Servicing is important because cars get battered and bruised on stages, and engineers can fit new parts to make the cars faster on different types of terrain.

THE WRC EXPLAINED

The World Rally Championship (WRC) is the sport's top level of competition – the rallying equivalent of Formula 1. The 2019 season had 13 events in countries like Mexico, Finland and Turkey, and the 2020 series will be staged across six continents for the first time. The WRC tackles different surfaces too, from the ice of Monte Carlo and the snow of Sweden to the gravel of Argentina and the tarmac of Germany. Teams spend millions to get the most out of their 380-horsepower cars – it's a big deal when manufacturers like Toyota, Citroën and Hyundai can claim that their cars are the toughest. Drivers win points for their overall positions, with those points added together to determine which team has done the best.

Wales Rally GB is the UK's WRC entry, and it takes place all over mid and north Wales. We attended the 2019 event with Citroën to find out how a top team handles the demands of one of the season's toughest events and to experience the magic of WRC for ourselves.

A WELSH ADVENTURE

A WRC round has been held in the UK almost every year since the championship's inception in 1973, and Wales Rally GB can trace its history all the way back to 1932.

It's an important historic event that's been won by every legend of the sport – drivers like Sébastien Loeb, Colin McRae and Richard Burns. It's also one of the toughest gravel events in the WRC, with stages that plunge through forests and run across remote ranges of hills.

Wales Rally GB is one of the year's most daring events

© Red Bull

A team of expert mechanics work flawlessly to keep WRC cars in race-ready condition

© Citroën World Rally Team

CITROËN
CITROËN
RACING
TOTAL
MICHELIN

263
The number of points achieved by champion Ott Tänak in the 2019 WRC season

Drivers have to travel on public roads in WRC events, not just on fast-paced stages

© Red Bull

Forest tracks are fast, slippery and difficult, with logs lining the roads

© Citroën World Rally Team

DID YOU KNOW? *More than 10,000 players compete in the WRC's esports events – the world champion wins a Hyundai i10*

The 2019 event was contested by some of the best drivers the WRC has ever seen. The Toyota Yaris squad was led by Ott Tänak, the Estonian who eventually won the 2019 drivers' title. Citroën's lead driver in the C3 was Sébastien Ogier, a modern-day icon who has won six WRC titles. The Hyundai i20 team centred around Thierry Neuville, who is one of the best drivers to never win the title. The UK-based M-Sport Ford team relied on Elfyn Evans in his Fiesta – the WRC's only Welsh driver. The 2019 event was made up of 22 stages that lasted for almost 200 miles across four days – and the drivers also had to tackle hundreds of miles of public roads.

Not all of the crews drive WRC cars. There are several different classes beneath the main WRC drivers: in WRC-2, crews drive more affordable versions of cars like the Fiesta, i20 and C3. There are Junior drivers in smaller vehicles, and more crews piloting older cars like the Subaru Impreza. That's one of the key things about rallying: enthusiastic amateurs can enter the same events as the famous drivers. Rallying isn't restricted to the WRC, either. There are rallies and championships all across the UK for top-level drivers and for those just starting out.

1,800

The number of volunteer marshals who help run Wales Rally GB

Hybrid technology will appear in WRC rallies from 2022 onwards

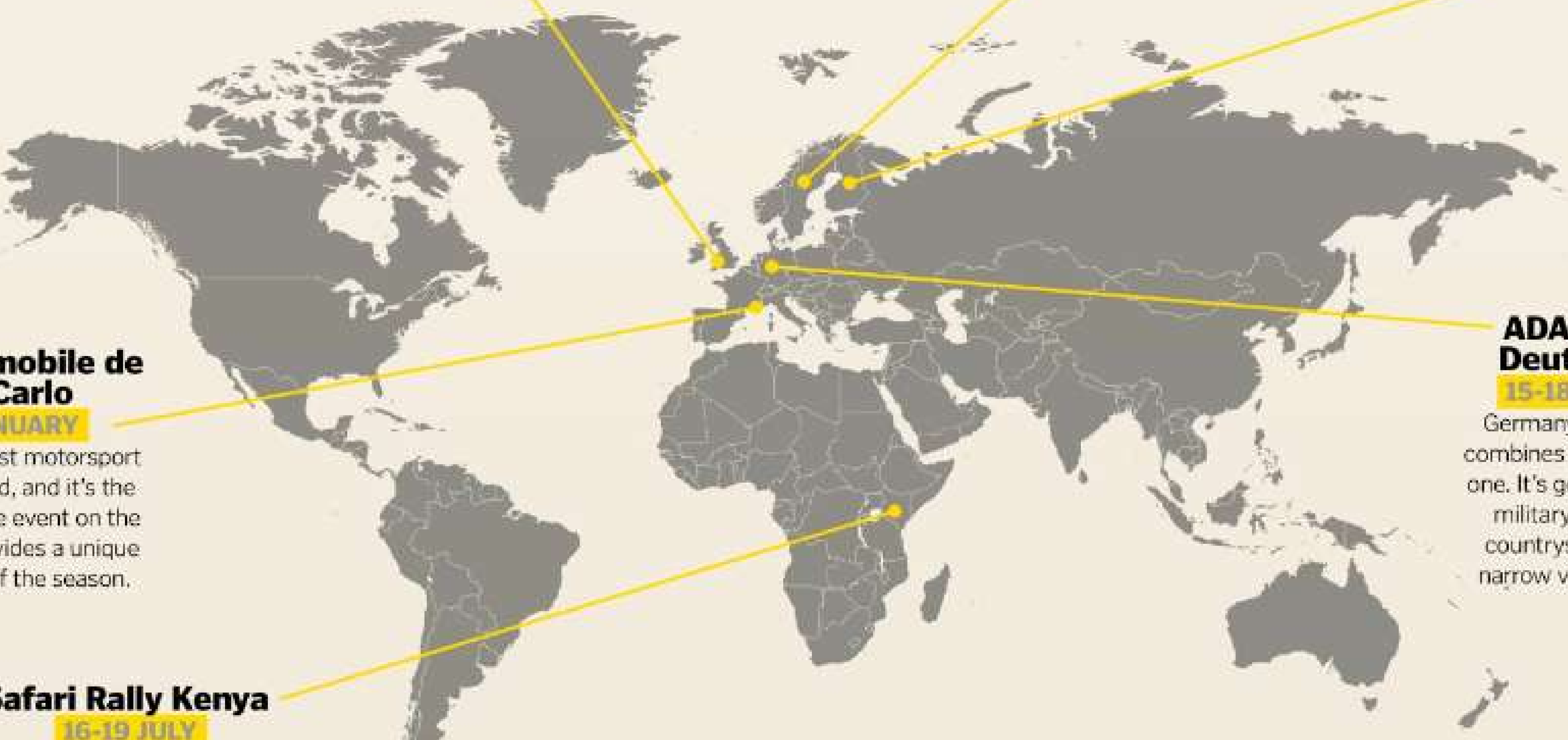
© Red Bull

The WRC embraces the future

The WRC will be going hybrid in 2022, with new cars that will use conventional petrol power on stages and electric engines for road sections. Pierre Budar is the director of Citroën Racing, and at Wales Rally GB he told us that he sees a huge opportunity to show off hybrid technology. "We have to learn how to use [hybrid]," he explained. "It will be demonstrative with no noise, no emissions, but it needs to bring something to the sport – so we are requesting that we can use this electric power during stages as an extra power source." There are challenges though. "The cost of the car will be difficult," said Budar. "It's a big challenge to produce the same level of performance using this new technology. The hybrid system will weigh around 100 kilograms, so we need to save weight with different designs and materials."

WRC 2020: big changes

The stages are set for a year of fierce competition



Wales Rally GB

29 OCTOBER-1 NOVEMBER

The UK's WRC event is moving later in the year for 2020, which means it's likely to be wetter, muddier and tougher for all of the drivers.

Rally Sweden

13-16 FEBRUARY

The year's only snow event means cars need special tyres – they're kitted out with extra-thin models that are packed with metal studs for extra grip.

Rally Finland

6-9 AUGUST

The fastest event on the calendar uses wide, sweeping roads with hundreds of exciting jumps. It's known as the Gravel Grand Prix for good reason.

Rallye Automobile de Monte Carlo

23-26 JANUARY

It's one of the oldest motorsport events in the world, and it's the only mixed-surface event on the calendar, so it provides a unique test at the start of the season.

ADAC Rallye Deutschland

15-18 OCTOBER

Germany's WRC event combines three rallies into one. It's got stages set on military tank ranges, countryside roads and narrow vineyard tracks.

Safari Rally Kenya

16-19 JULY

The Safari Rally is a classic, and it's back for the first time since 2002. Expect gravel, rough terrain and perhaps some animals on the stages.

> *"For fans, attending the rally is an adventure of its own – something you don't get in any other motorsport"*

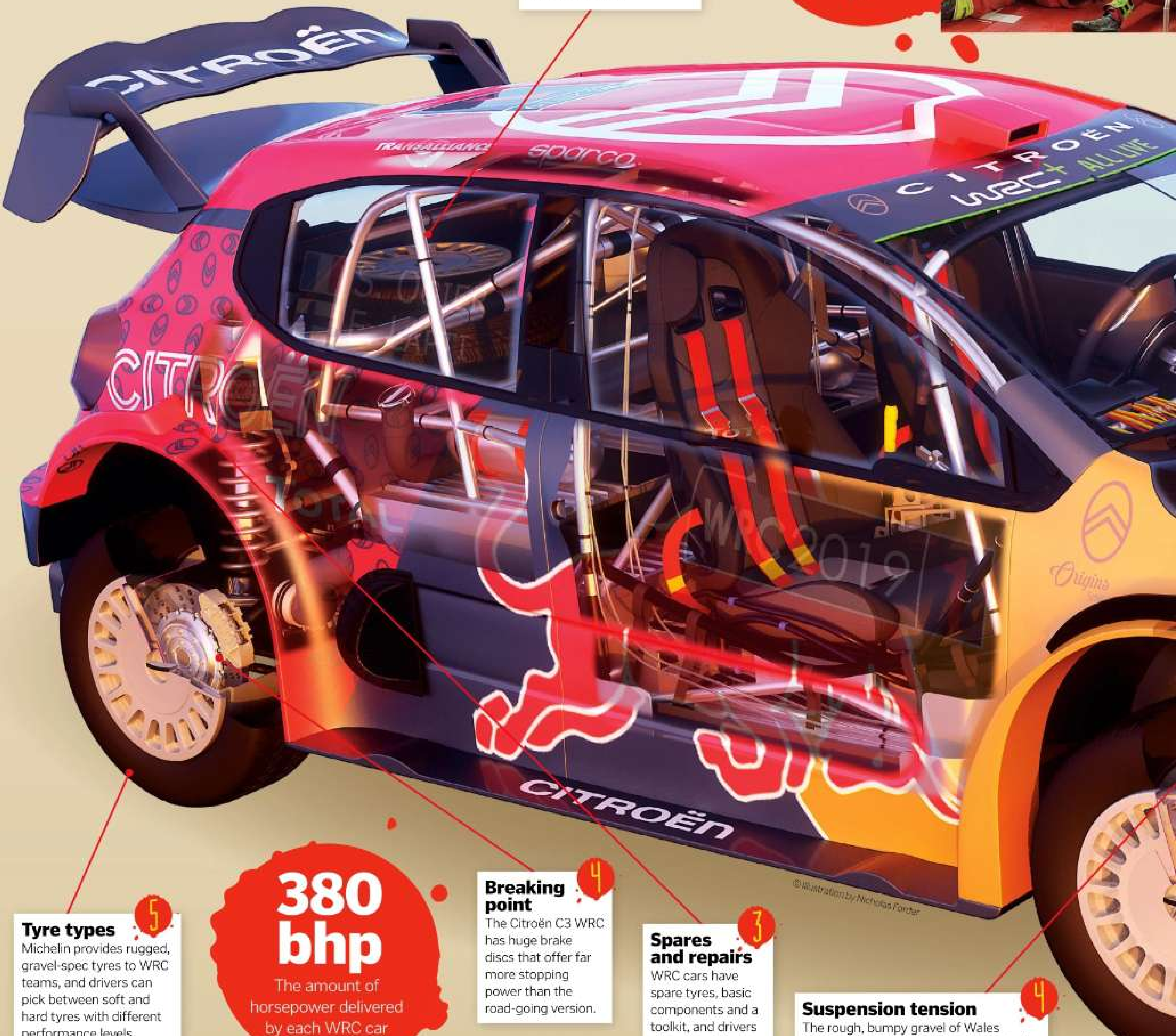
A WORLD RALLY CAR EXPLORED

WRC cars are the toughest machines in motorsport – we get hands-on with the Citroën C3

AR ZONE!
SCAN HERE

14,208
The hours of WRC content broadcast annually to 155 countries

Caged in 3
A sturdy metal roll cage helps the car keep its shape if it rolls over so drivers stay safe in accidents.



© Illustration by Nicholas Forder

Tyre types 5
Michelin provides rugged, gravel-spec tyres to WRC teams, and drivers can pick between soft and hard tyres with different performance levels.

380 bhp
The amount of horsepower delivered by each WRC car

Breaking point 4
The Citroën C3 WRC has huge brake discs that offer far more stopping power than the road-going version.

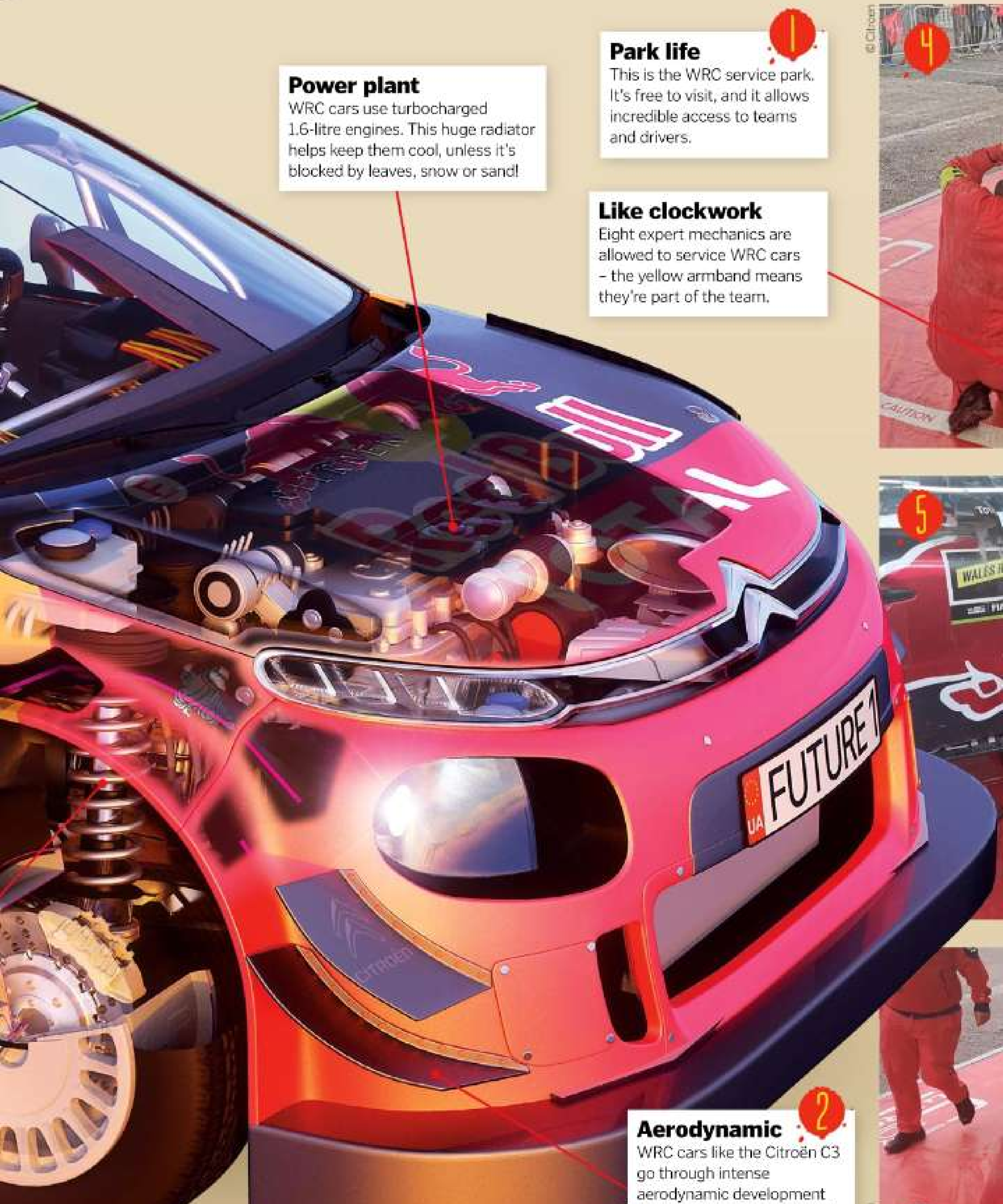
Spares and repairs 3
WRC cars have spare tyres, basic components and a toolkit, and drivers often repair their cars on the road.

Suspension tension 4
The rough, bumpy gravel of Wales demands tough suspension – this shock absorber runs all the way up into the car.

© Citroen

© Citroen

© Citroen



1

Park life

This is the WRC service park. It's free to visit, and it allows incredible access to teams and drivers.

Power plant

WRC cars use turbocharged 1.6-litre engines. This huge radiator helps keep them cool, unless it's blocked by leaves, snow or sand!

Like clockwork

Eight expert mechanics are allowed to service WRC cars – the yellow armband means they're part of the team.

2

Aerodynamic

WRC cars like the Citroën C3 go through intense aerodynamic development so the car stays on the road and handles smoothly.

© Citroen

© Citroen

VISITING THE WRC

WRC events follow a similar structure to Wales Rally GB: the service park is assembled in one location – Llandudno in this case – with the teams heading out to tackle stages in the morning and returning at lunchtime and in the evening to service their cars. WRC events have a ceremonial start, usually in a big city, and they usually have a stage in cities or at racing circuits in the evening for easy spectator access. And then, at the end of each event there's the Power Stage – a special run where drivers can earn extra championship points if they're brave enough to really attack the road.

For many fans, attending the rally is an adventure of its own – something you don't get in any other motorsport. There's nothing quite like attending a rally: you wake up early, pulling on waterproofs and wellies before driving through the sunrise to the stunning, atmospheric forests. It's easy to find spots right next to the stages – as long as the marshals say you're in a safe place. Watching the rally in person is sensational. You hear the cars first, their monster engines echoing around the trees, and then the drivers arrive, hurling their million-pound machines around corners as quickly as possible.

When the stage is over, you can head back to your car and drive to another – and if you're lucky you'll see some of the WRC cars doing the same thing. It's an exciting, surreal experience. Stages are relatively cheap to attend, and the service park is free, so fans can get up close to cars and get pictures with the top drivers.

Rallying is incredibly accessible, and incredibly exciting. There's no other motorsport where powerful racing cars are challenged by so much tough, varied terrain – and few other sports make it so easy to get so close. We're going to dive deeper into the sport here, including exploring the future and finding out what a typical day is like for a champion driver – and we'll see you on the stages when Wales Rally GB returns on 29 October 2020.

sparco
namic

Rally cars are based on road cars, but they're beefed up and stripped back to improve performance

© Red Bull

59
The number of crews that contested Wales Rally GB 2019 – only 47 finished

The road to success

WRC cars are based on road-going models – Toyota has the Yaris, while Hyundai uses the i20 and Ford has its Fiesta. However, few of the original cars' parts are used on rally versions – the underlying chassis and overall shape is the same, but that's about it.

Components like the engine, suspension and brakes need to be made more powerful and robust. A roll cage is added to improve safety, and the driver and co-driver need moulded seats, stronger seatbelts, fire extinguishers and an intercom. Spoilers and aggressive aerodynamic features are added. It's vital to save weight too. Virtually every component is either removed or made from lighter materials. WRC car interiors are bare – a prime example of function over form.

© Jon Armstrong

Q&A

ARE YOU READY DRIVER?

WRC 2018 eSports champ Jon Armstrong has driven on rally courses across Europe

How do you prepare for driving stages as quickly as possible?

We have to get to the stage by a certain time – sometimes we refuel on the way. We'll pull up a mile before the stage. I'm superstitious so I do everything in the same order – check tyre pressures, put my left glove on before my right glove, put our helmets and seatbelts on and hook up the intercom.

Rally days look very intense – what's your routine like?

We're up early, so we put our fireproof underwear, race suits and boots on straight away. We'll grab breakfast at service – I have something simple, like porridge or an omelette. We talk with our crew about the day ahead, do basic car checks and try and get information about the stage conditions so we can choose which tyres to use.

Between stages we have water, energy bars and fruit. It's important to keep blood sugar constant – you don't want to be tired, but you don't want to spike and crash later. After service, we'll eat a good source of protein with some vegetables. I'll check my notes for the next day, shower and head to bed. I prioritise sleep because these are 12- or 14-hour days – recovery is important.

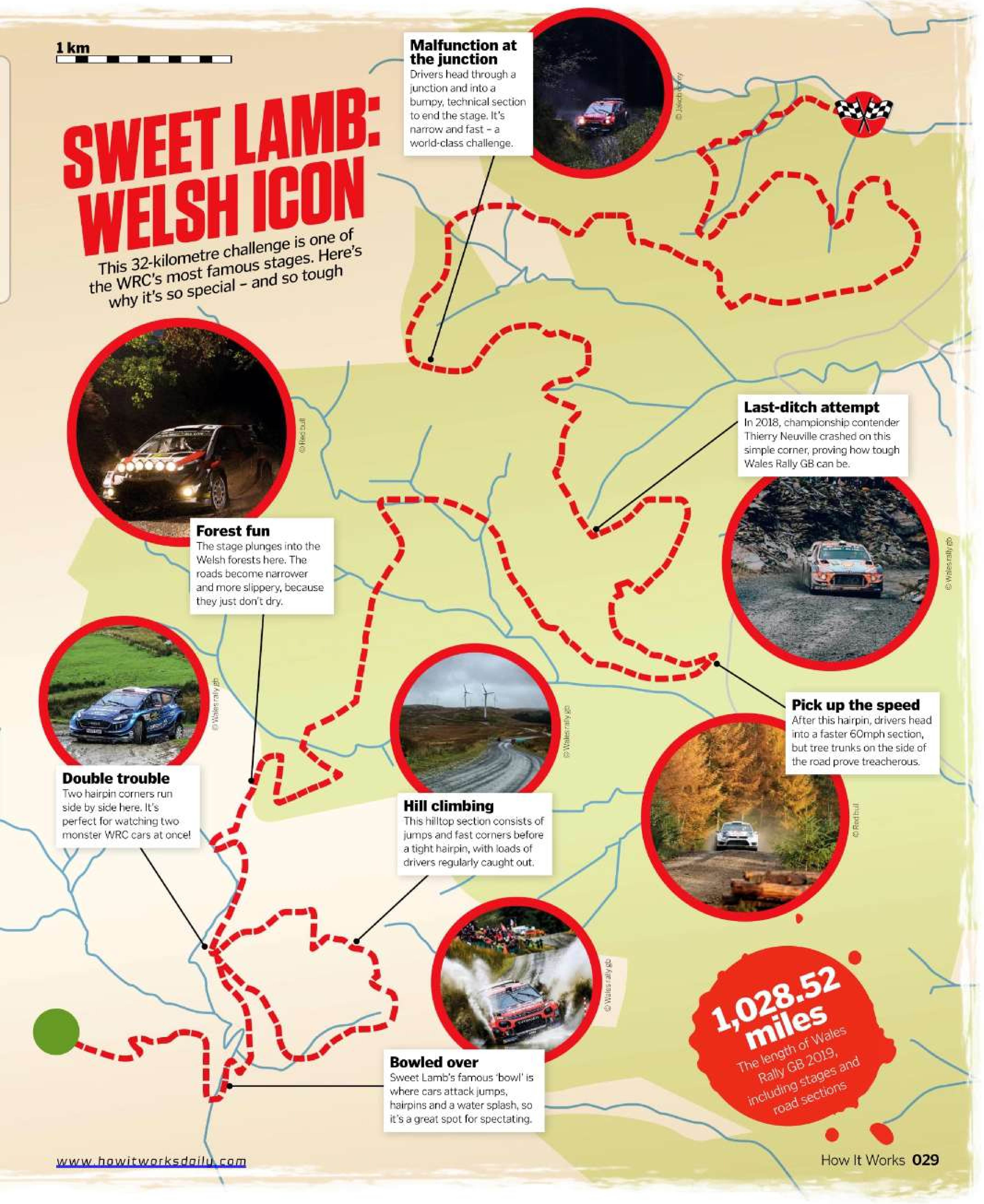
How do you get ready for events?

We recce the stages to create our notes. We drive the rally twice, slowly, in a road car. We make notes down to every metre so we know how fast to drive the stage and what obstacles we'll encounter. On the first pass I'll call out what the corner looks like, and my co-driver Noel writes it down. On the second pass he'll read back what he's written so we can make finer adjustments. Recce is vital – you need a good balance between caution and speed.

Jon Armstrong has competed at Wales Rally GB and in Spain, Finland, Portugal and Germany

SWEET LAMB: WELSH ICON

This 32-kilometre challenge is one of the WRC's most famous stages. Here's why it's so special – and so tough



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Malfunction at the junction
Drivers head through a junction and into a bumpy, technical section to end the stage. It's narrow and fast – a world-class challenge.

Forest fun
The stage plunges into the Welsh forests here. The roads become narrower and more slippery, because they just don't dry.

Last-ditch attempt
In 2018, championship contender Thierry Neuville crashed on this simple corner, proving how tough Wales Rally GB can be.

Pick up the speed
After this hairpin, drivers head into a faster 60mph section, but tree trunks on the side of the road prove treacherous.

Double trouble
Two hairpin corners run side by side here. It's perfect for watching two monster WRC cars at once!

Hill climbing
This hilltop section consists of jumps and fast corners before a tight hairpin, with loads of drivers regularly caught out.

Bowled over
Sweet Lamb's famous 'bowl' is where cars attack jumps, hairpins and a water splash, so it's a great spot for spectating.

1,028.52 miles
The length of Wales Rally GB 2019, including stages and road sections

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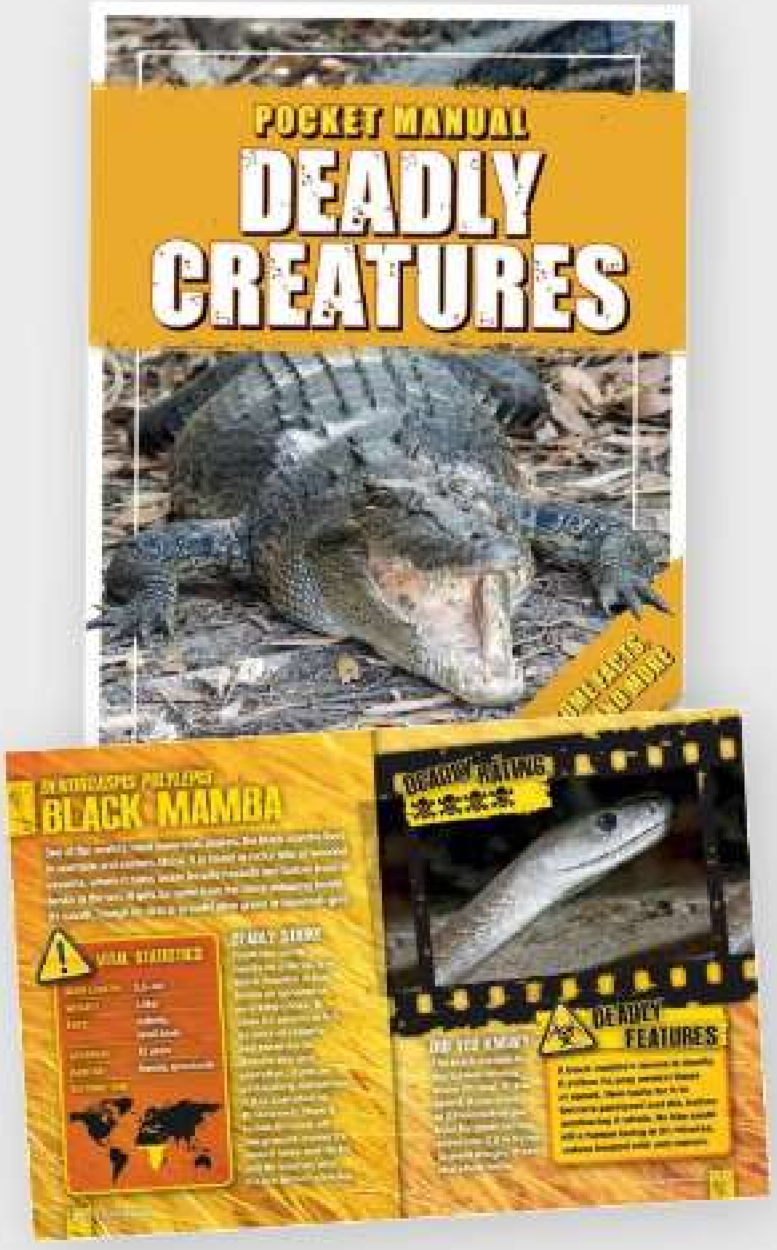
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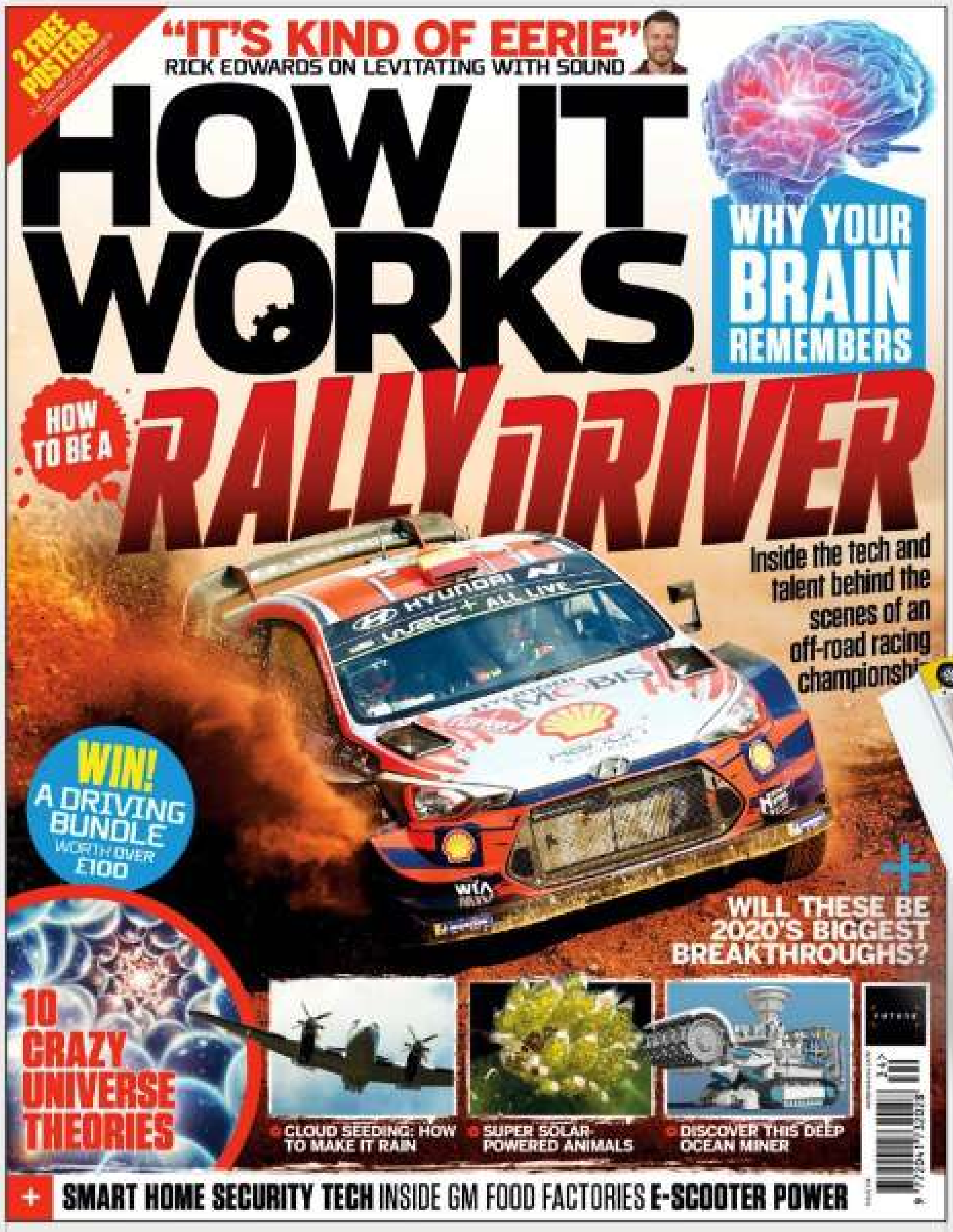
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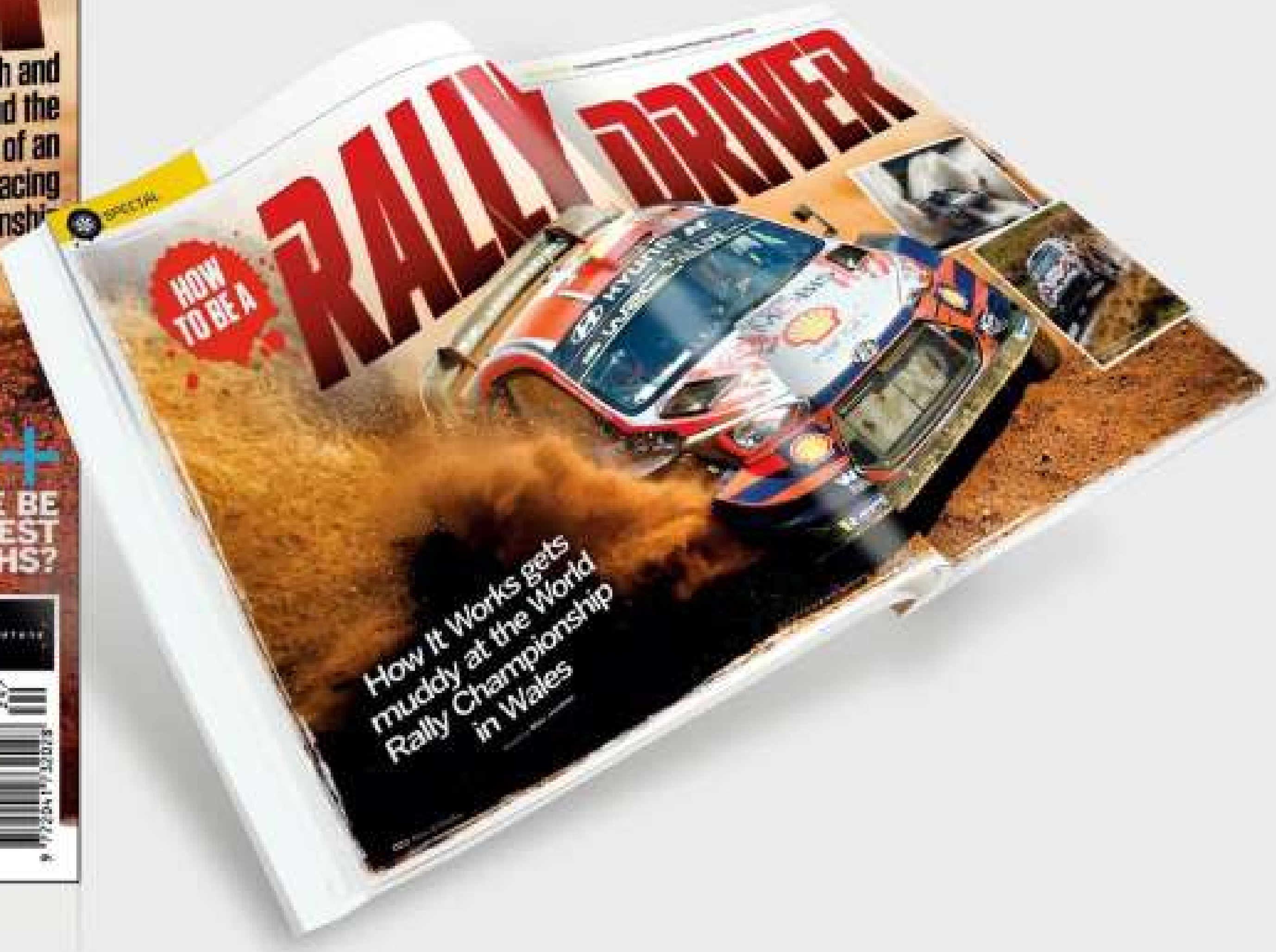
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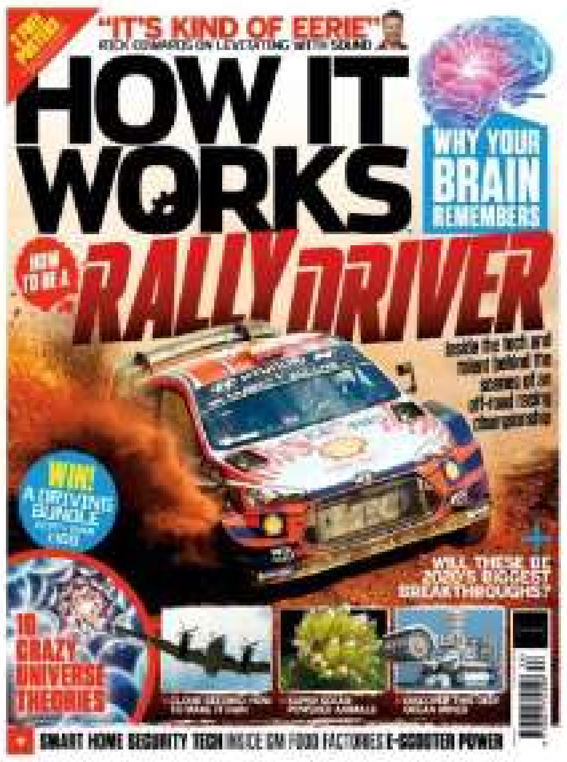

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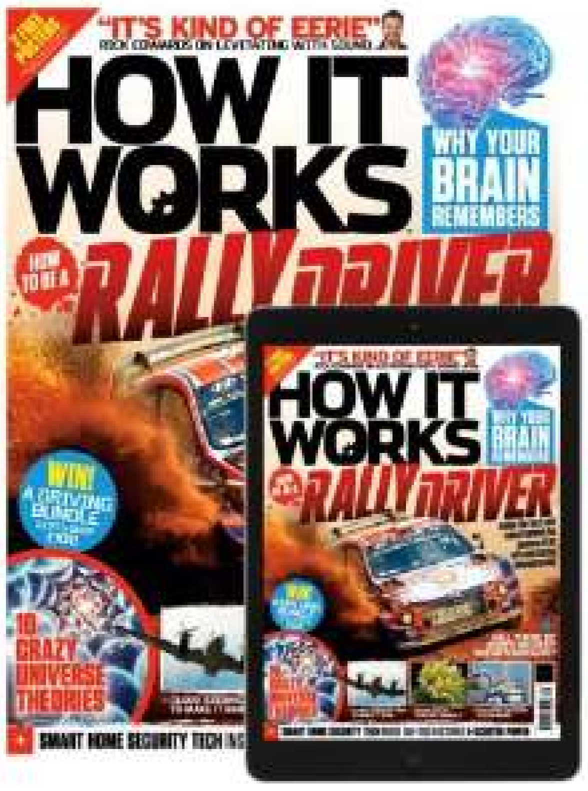

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E-scooters: the future of travel

The SEAT e-Scooter has a removable battery, so you can have two charging at once

© SEAT

Electric scooters are gaining ground – should you get one when you want to get moving?

Words by **Mike Jennings**

Electric vehicles are big business, but up until now the market has concentrated on cars. These days, though, electric bikes and scooters are getting more attention. It's long overdue too, because electric bikes have been around since the 1890s. BMW gained a lot of attention with its C Evolution back in 2016, and now SEAT has launched its own model, the e-Scooter.

It's easy to see why these devices are proving popular. More people are living and working in cities than ever before, which means that people need small, manoeuvrable bikes and cars to get around cities where traffic is a real problem.

In the past, petrol-powered mopeds have done the job. They're hugely popular in most European cities, including Barcelona, where SEAT launched the e-Scooter. But now, with more focus on the environment, people are demanding electric options. These new devices are great, but they also have challenges. A lot of cities just don't know how to handle them. New laws need to be created so people can actually use them safely. There's also the fact that there are two kinds of device that could be described as an electric scooter.

The BMW C Evolution and SEAT e-Scooter look like traditional mopeds, and they're sometimes called 'maxi-scooters' or 'electric mopeds'. However, e-scooters can also be two-wheeled devices that look like children's scooters. These products have batteries and can often be rented in cities – just like Boris Bikes in London – and are often also called 'kick scooters'.

These smaller scooters are big business in America, where Uber and Lyft are getting involved, and companies like Lime are rolling them out in London, Paris, Berlin and Sydney. Because they're rented, they're cheap – and because they're tiny, you don't need a driving license to use one.

> *"More people are living and working in cities than ever before – which means that people need small, manoeuvrable bikes"*

Charge it up

You could argue that the battery is the most important part of an electric scooter. After all, if that's rubbish then you're not going anywhere.

The bad news is that, for the foreseeable future at least, electric vehicle capacities and ranges will struggle to match petrol and diesel cars and bikes – and these new vehicles will continue to be expensive because batteries aren't cheap.

But the situation is improving: in 2015 the battery took up more than 50 per cent of the cost of the average electric car, but that figure is down to around 30 per cent now.

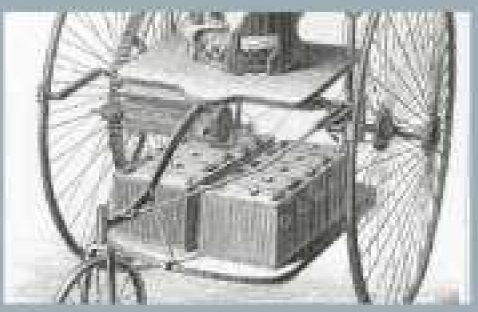
Batteries are becoming more efficient too. The BMW C Evolution launched with a 100-kilometre range and a power output of 15 horsepower. The current model lasts just under 160 kilometres with a 26-horsepower output.

© BMW

BMW's electric scooter is getting better – and more manufacturers will follow suit

New take on old tech

Electric bikes have existed in some form for over 120 years



1895

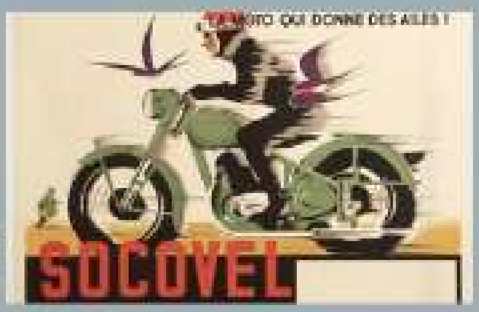
The first patent for an electric bicycle is filed in Ohio – and they probably existed before this date.

1896

British cycle company Humber displays the first electric tandem – and a year later it travels at a record-breaking 60kph.

1919

In Britain, electric bikes with sidecars full of batteries are developed by the agricultural and general engineering company Ransomes, Sims & Jefferies. In its prototype the batteries are placed underneath the sidecar seat. This never made it through its trials, however. Meanwhile, petrol-powered scooters begin to gain popularity and development pulls ahead of electric bikes.



1941

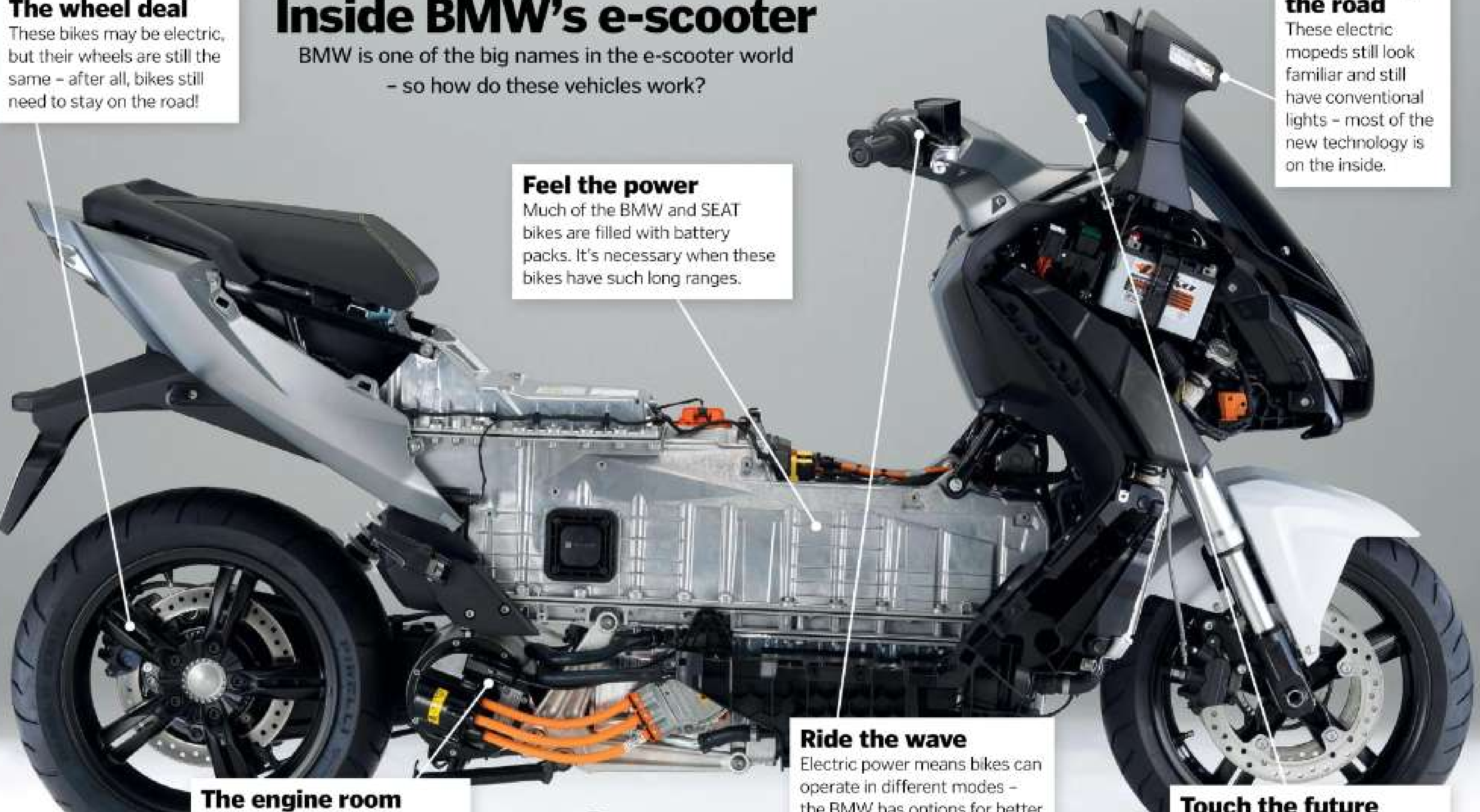
A new company called SOCOVEL begins to sell electric scooters because petrol was hard to find during World War II.

1967

Scientists develop better batteries for electric bikes, and the famous old brand Papoose begins to sell electric bikes. The same year, chemist Karl Kordesch invents a hydrazine fuel cell battery for a motorcycle. It's the same compound that powers some rockets. The hybrid bike can travel up to 320 kilometres on a gallon of petrol, with a top speed of 40kph.

Inside BMW's e-scooter

BMW is one of the big names in the e-scooter world – so how do these vehicles work?



The wheel deal
These bikes may be electric, but their wheels are still the same – after all, bikes still need to stay on the road!

Feel the power
Much of the BMW and SEAT bikes are filled with battery packs. It's necessary when these bikes have such long ranges.

Lighting up the road
These electric mopeds still look familiar and still have conventional lights – most of the new technology is on the inside.

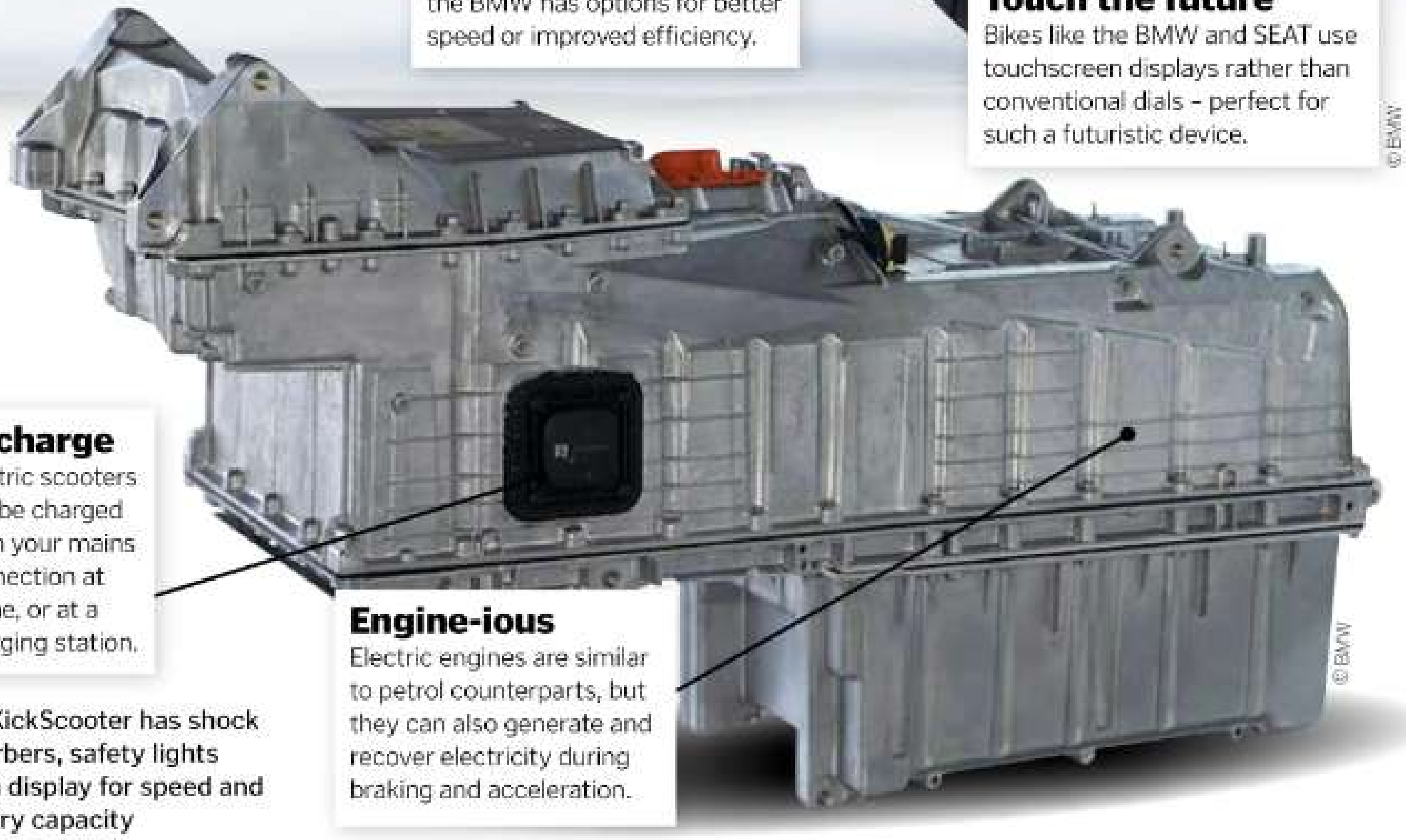
The engine room
Electric scooters use engines that balance speed and efficiency. They can also generate electricity when the bike is braking.

Ride the wave
Electric power means bikes can operate in different modes – the BMW has options for better speed or improved efficiency.

Touch the future
Bikes like the BMW and SEAT use touchscreen displays rather than conventional dials – perfect for such a futuristic device.

© BMW

The KickScooter has shock absorbers, safety lights and a display for speed and battery capacity



In charge
Electric scooters can be charged from your mains connection at home, or at a charging station.

Engine-ious
Electric engines are similar to petrol counterparts, but they can also generate and recover electricity during braking and acceleration.

© BMW

1975
American inventor Mike Corbin releases the City Bike, which is an electric bike with a 64-kilometre range. It's based on a street-legal electric commuter bike that he developed a few years prior and named after himself. He also sets the world record for the top speed on an electric motorcycle, hitting just over 265kph on a bike that was named Quicksilver.

© Wikimedia/Tennen-Gas

1991
Lithium-ion batteries are invented – a huge leap forward because it means more power can be stored in a smaller space.

© Peugeot

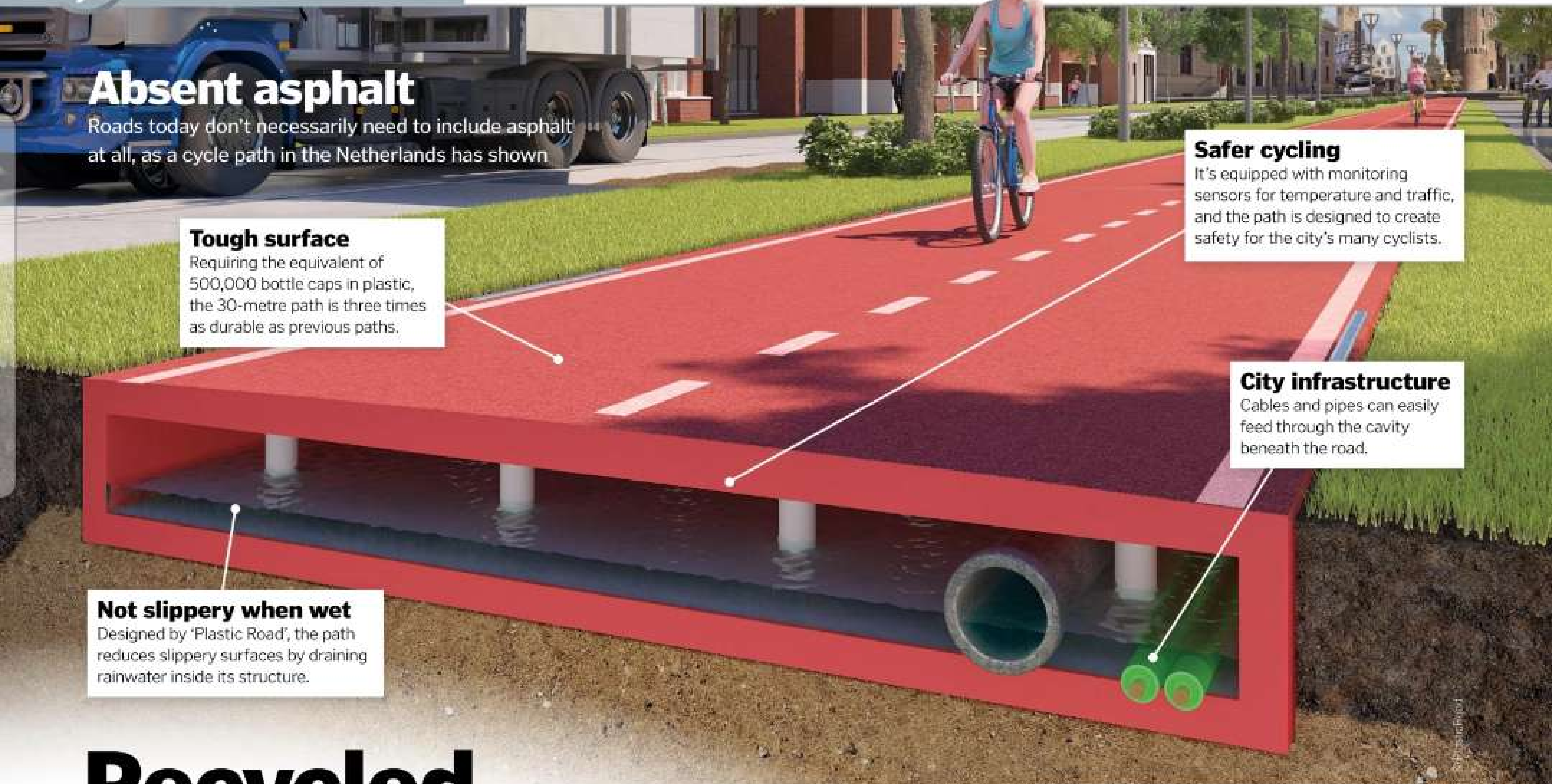
1996
Peugeot releases its Scoot'Elec – a successful electric scooter that is manufactured for ten years and has a 40-kilometre range.

© BMW

2014
BMW releases its C Evolution electric scooter – the first major car company to release this kind of device since Peugeot.

© Lime

2017
Lime only launched a couple of years ago, and its scooter-rental business is already in more than 100 cities worldwide.



Absent asphalt
Roads today don't necessarily need to include asphalt at all, as a cycle path in the Netherlands has shown

Tough surface
Requiring the equivalent of 500,000 bottle caps in plastic, the 30-metre path is three times as durable as previous paths.

Safer cycling
It's equipped with monitoring sensors for temperature and traffic, and the path is designed to create safety for the city's many cyclists.

City infrastructure
Cables and pipes can easily feed through the cavity beneath the road.

Not slippery when wet
Designed by 'Plastic Road', the path reduces slippery surfaces by draining rainwater inside its structure.

© PlasticRoad

Recycled plastic roads

We can pave a future out of the plastic problem by turning it into a kind of tarmac

We live in a world where over 400 million tonnes of plastic are produced each year. Of this volume, 75 per cent gets thrown away, damaging ocean life and packing landfills full. Recycling these materials has become more important than ever, and one way people are beginning to tackle this problem is by creating roads out of plastic.

Recycled roads can use up to 684,000 plastic bottles or nearly 2 million single-use plastic bags in every kilometre. Comparing current roads to the properties we see in a plastic bottle, you may wonder how these roads fare in safety. Tests have shown that including plastic into road mixtures actually improves strength, it proving to be twice as strong and withstanding heavy traffic.

The reason for their improved durability is thought to be the flexible properties of plastic. Their bounce-back ability after displacement from weight gives them an almost self-repairing property that asphalt roads lack. As well as this, the roads continue to establish the same essential qualities such as being weatherproof while reducing flaking and potholes.

Using alternative materials, such as plastic, these recycled roads combat two issues at once. While putting waste material to use instead of damaging surrounding environments, these roads also cut down on the amount of bitumen used to make asphalt roads. Creating more sustainable roads, less oil will be demanded for production, as fossil fuels are rapidly depleting. For each tonne of bitumen that plastic replaces in these roads, a tonne of carbon dioxide is reduced in production. And why stop at plastic for alternative and sustainable sources? Further projects include the use of old tyres and even the waste products from olive oil extraction.

© Getty

Plastic waste is shredded into pellets before impurities such as paper labels are separated

How roads can be more eco-friendly

Creating a structurally sound road from plastic seems like a complex task. First the plastic bottles, bags and other items are washed and cut down into small pellets. These are melted at soaring temperatures of 170 degrees Celsius to combine with the asphalt mix. The resulting blend is used by workers to layer smooth roads as they usually would.

Pellets can vary in specific plastics, creating roads with slightly different properties. Road manufacturers can choose from three types of plastic pellets to buy, ranging in flexibility and durability. For example, in roads that will be used for the transportation of heavy trucks and machinery, the stronger pellets will be chosen. An example of where plastic varieties are essential is in the Middle East. Here, pellets need to be made from plastics that can resist becoming misshapen in the extreme and constant heat.

Road layering taking place with a recycled plastic and asphalt mix

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HOW DOES THE BRAIN REMEMBER?

Discover how this vital organ stores and utilises memories in a process essential to life as we know it

Words by **Ailsa Harvey**

Where would we be without memory? Without the ability to remember significant events in our lives we would lose sense of who we are, and being unable to store information as we learn it would leave us with the permanent intelligence of a newborn.

Your memory is made up of information that's been stored in the brain and can be retrieved. It enables us to learn from experiences, build trust and understanding, develop skills through training and simply compose a thought. Memory doesn't merely let us memorise a shopping list – it allows us to have a meaningful life.

The impressive structure of the brain is so complex that scientists are constantly working to gain a better understanding of its true capabilities. Most animals have working memories, but these differ greatly – from dogs that can forget events after only two minutes to dolphins who are thought to have the best long-term memory of the entire animal kingdom.

© Getty

Witnessing something unusual is more likely to remain in your memory

Actions taken from recalling past memories and imagining future plans are critical to our species' survivability. The majority of other animals have adapted to store only the memories that will help them to survive. Some, such as squirrels and the chickadee bird, bury food to help them survive through harsh winters. This would be of no use at all if they weren't equipped with the memory function to relocate them. Chickadees' impressive recall allows them to find their 80,000 hidden seeds all by memory.

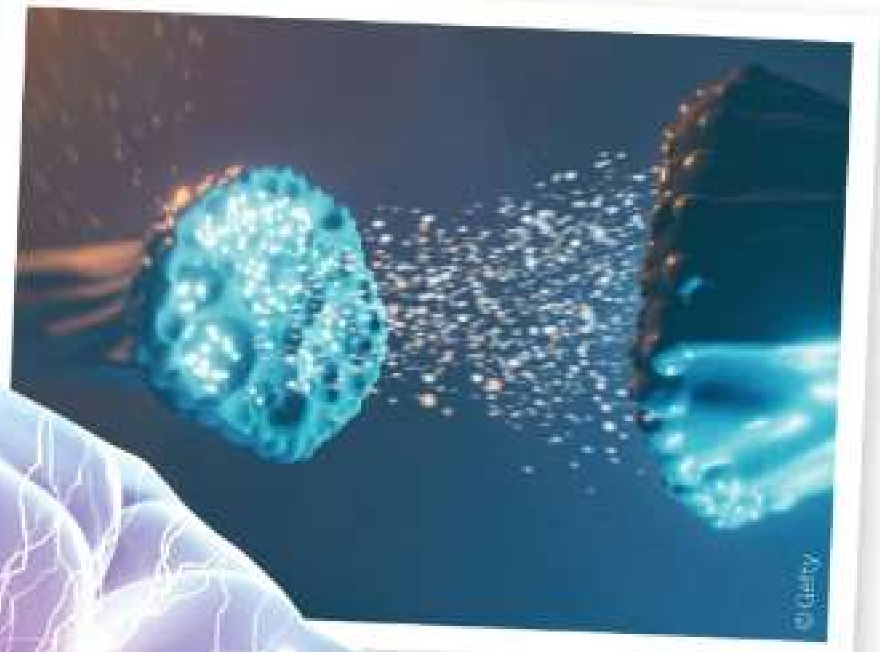
Our memories don't all serve a life-or-death purpose. Events that hold high significance to us are more likely to be remembered later down the line. For example, those that spark strong emotions stay with us, as strong connections are formed in the brain.

As soon as a memory is created, it needs to be stored. Because remembering everything would overload our brains, memories are taken through a filtering process. The brain takes in everything experienced by the senses. From this mass of events, the ones that had the most impact on the brain are stored first as short-term memories. These memories will only be recalled for a limited time, with some very fleeting and lasting just 20 seconds.

"Memory allows us to have a meaningful life"

Those that are reused are deemed to be important, and they become stronger each time they are recalled. This being said, every time you retrieve the same memory of an event from your brain, it is altered slightly in some way. Because of this, no memory ever stays identical through life; they are more like continuously adapting reconstructions.

DID YOU KNOW? *The human brain starts to remember things just 20 weeks after conception*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Neurons make new connections with each other every time a new long-term memory is made

Making memories: the biology of remembering

Sensing

The very beginning involves the exposure to surrounding scenes and situations. Various sights and sounds are experienced by your senses.

Encoding

With the sensory information passed to the brain, the volume and complexity is too great to process. Our brain selectively chooses aspects. Close attention is paid to unusual events, while encoded everyday occurrences are less likely to be replayed later in a memory.

Consolidation

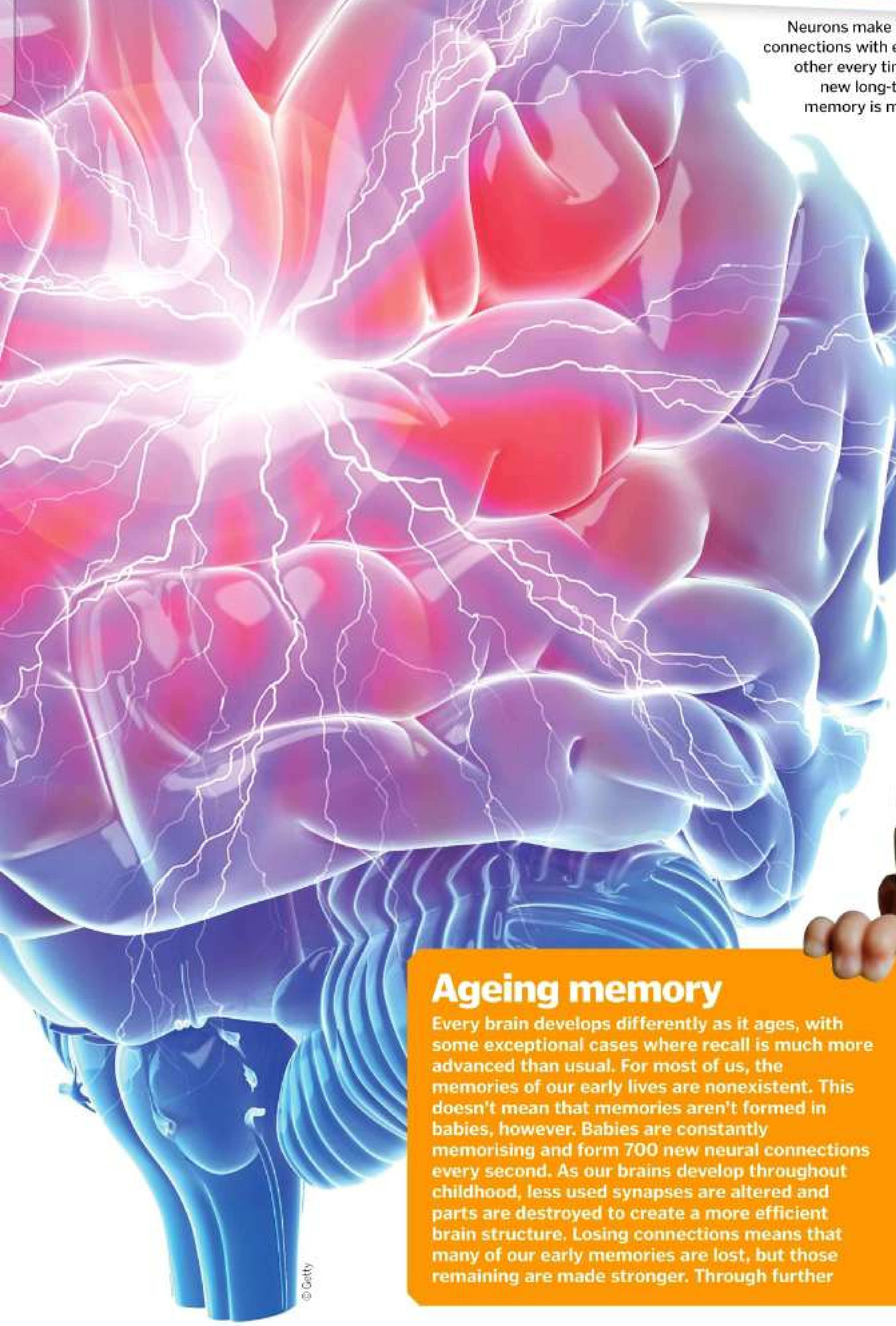
To deep-root these memories in the brain, consolidation is essential. By putting the encoded experience together into a stable, long-term memory, this process strengthens signals between neurons in the brain required for recall.

Storage

After being consolidated into a memory, it needs to be stored within the brain where it can be easily accessed. The full memory is not stored, however. Memory traces are stored to serve more like an aid, prompting our brains to reconstruct events as we experienced them as accurately as possible using the selected aspects encoded.

Retrieval

Thousands of events can be stored as memory traces, but these are useless if irretrievable. While most memories will never be used, some can be brought forward using retrieval cues. A song you heard could trigger a memory trace. When we think back to a time, relevant memories surrounding this can also be retrieved. Once the memory trace is activated, it is more likely to be reactivated in the future.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In a process called memory pruning, the brain gets rid of less important memories from early childhood

© Getty

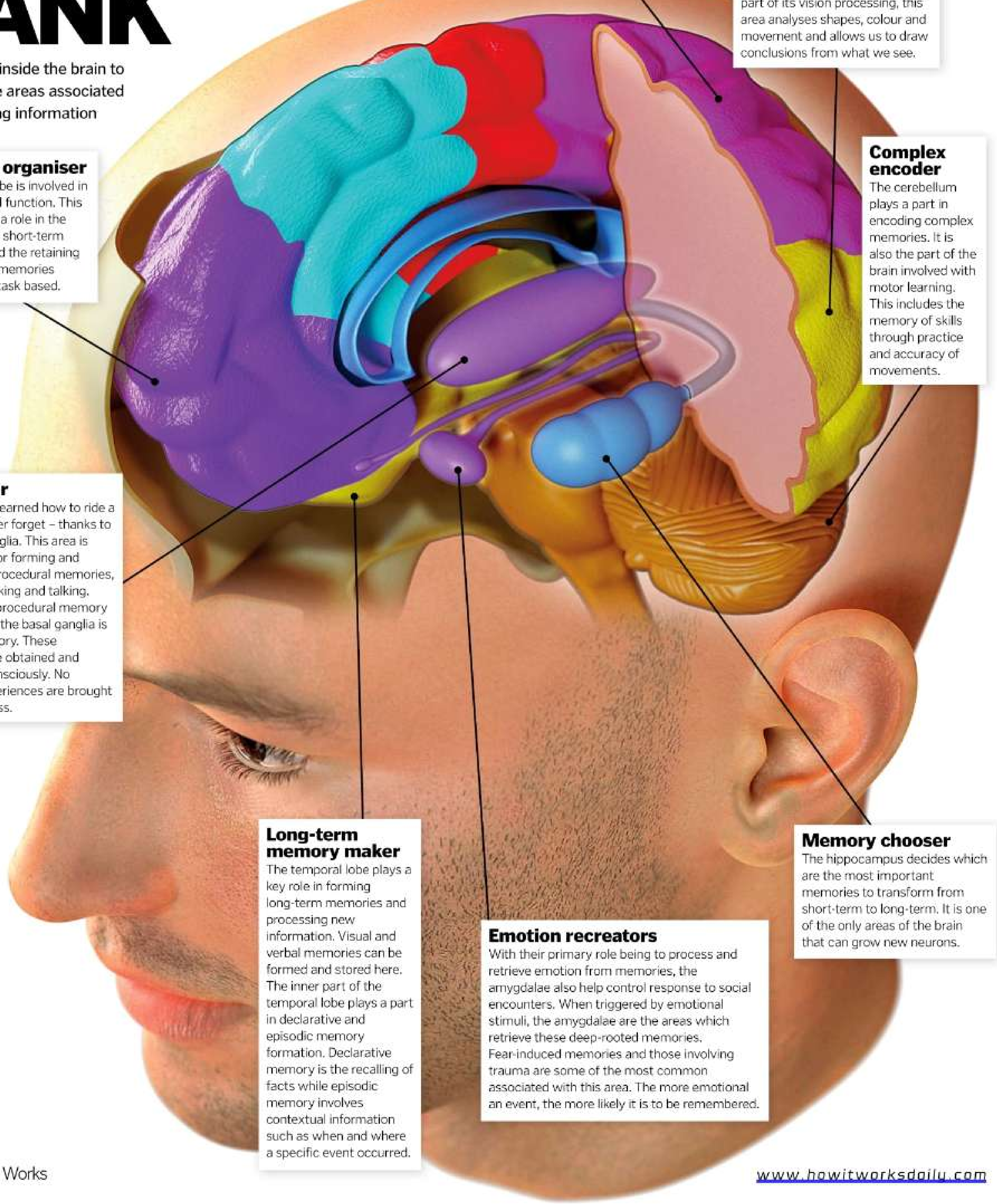
Ageing memory

Every brain develops differently as it ages, with some exceptional cases where recall is much more advanced than usual. For most of us, the memories of our early lives are nonexistent. This doesn't mean that memories aren't formed in babies, however. Babies are constantly memorising and form 700 new neural connections every second. As our brains develop throughout childhood, less used synapses are altered and parts are destroyed to create a more efficient brain structure. Losing connections means that many of our early memories are lost, but those remaining are made stronger. Through further development, our complex memory is better able to retain and recall long-term memories. With old age, some brain areas can shrink in size. One of these is the hippocampus, which loses five per cent of nerve cells every decade. This causes communication between neurons in the brain to slow down. Additionally, cell loss at the front of the brain towards the end of life causes a decrease in production of the essential neurotransmitter, acetylcholine. For these reasons, some people's ability to encode new information, and retrieve memories already formed, reduces as they become older.

INSIDE THE MEMORY BANK

Take a look inside the brain to discover the areas associated with recalling information

AR ZONE! SCAN HERE



Senses incorporator
The parietal lobe is involved in the first step of memory formation, using the senses experienced to create memories. This section is also responsible for triggering retrieval when encountering the same sensory information again.

The visualiser
This section of the brain – the occipital lobe – is responsible for linking images to memories. As part of its vision processing, this area analyses shapes, colour and movement and allows us to draw conclusions from what we see.

Memory organiser
The frontal lobe is involved in higher mental function. This section plays a role in the processing of short-term memories and the retaining of long-term memories which aren't task based.

Complex encoder
The cerebellum plays a part in encoding complex memories. It is also the part of the brain involved with motor learning. This includes the memory of skills through practice and accuracy of movements.

Bike rider
Once you've learned how to ride a bike, you never forget – thanks to the basal ganglia. This area is responsible for forming and recalling all procedural memories, including walking and talking. One form of procedural memory controlled by the basal ganglia is implicit memory. These memories are obtained and applied unconsciously. No previous experiences are brought into awareness.

Long-term memory maker
The temporal lobe plays a key role in forming long-term memories and processing new information. Visual and verbal memories can be formed and stored here. The inner part of the temporal lobe plays a part in declarative and episodic memory formation. Declarative memory is the recalling of facts while episodic memory involves contextual information such as when and where a specific event occurred.

Emotion recreators
With their primary role being to process and retrieve emotion from memories, the amygdalae also help control response to social encounters. When triggered by emotional stimuli, the amygdalae are the areas which retrieve these deep-rooted memories. Fear-induced memories and those involving trauma are some of the most common associated with this area. The more emotional an event, the more likely it is to be remembered.

Memory chooser
The hippocampus decides which are the most important memories to transform from short-term to long-term. It is one of the only areas of the brain that can grow new neurons.

© Illustration by Nicholas Forder

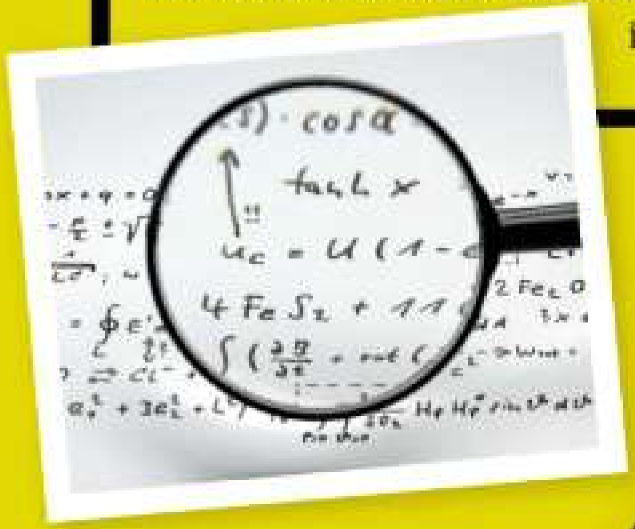
DID YOU KNOW? *Our brains are thought to be able to hold the entire internet's worth of information in their memory*

TIPS FOR A BETTER MEMORY

How you can improve your memory by making changes in your day-to-day life

Pay attention

To move information from your short- to long-term memory, paying attention and taking the time to understand information helps. Neural circuits that help build long-lasting memories work best when we focus on our surroundings. Neurotransmitters released when we're attentive target areas involved in processing visuals.

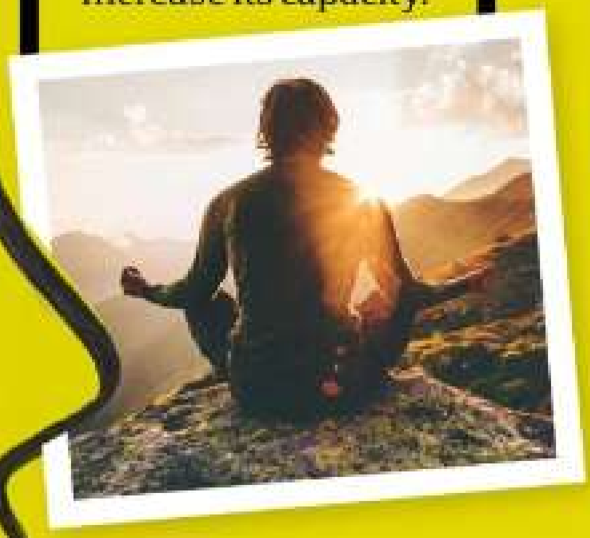


Get enough sleep

For memory consolidation to take place, your body needs sleep. While you are asleep, connections in the brain can strengthen and information can pass into more permanent and efficient regions of the brain. Research shows that when information is learned before sleeping, it is remembered better.

Try meditating

Mindfulness is proven to enhance the abilities of your working memory. This is where new information is temporarily held. Most adults are able to hold around seven items in their working memory, but meditation is thought to strengthen it and increase its capacity.



Stimulate your brain

Testing your cognitive ability has been found to reduce early symptoms of memory loss. By taking part in brain games, your frontal lobe enhances its ability to split your attention between mental tasks. Keeping your brain used to memorising and keeping neuron connections activated can increase their efficiency.

Exercise regularly

Physical activity has been proven to have a direct impact on brain health. By regularly exercising, the risk of cognitive decline becomes lower. By stimulating brain growth, studies have shown that in those who regularly exercise, parts of the brain key to memory production are larger.

Drink less alcohol

Alcohol consumption has obvious impacts on memory ability. People who drink regularly make around 30 per cent more memory mistakes in daily life than those who don't drink. Alcohol works to prevent transfer of short-term memories to long-term and even reduces the size of brain cells. After a heavy night of drinking, it's possible to have no memory of events. This is due to a memory-affecting chemical in the brain called glutamate, which is extremely susceptible to alcohol.

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INTERVIEW

How to levitate

Imagine a world in which wheels were no longer a necessity, where medicine could be hand-delivered within the body, where buildings rise above the ground during an earthquake – a world where gravity is optional. This hypothetical world might be closer than we think, as TV presenter, author and podcast host Rick Edwards has discovered in a BBC Studios YouTube Original. The Edge of Science follows Edwards and a team of popular YouTube creators, including inventor Colin Furze and MIT physics graduate Dianna Cowern, as they attempt to achieve the seemingly impossible: human levitation. From levitation by sound to using supercooled material to create a hoverboard straight from science fiction, Edwards sheds some light on what it's like to float.

Rick Edwards graduated with a degree in natural sciences from Cambridge University before becoming a journalist, presenter and author

© BBC Studios

During your career you have explored many avenues in science. What inspired you to investigate the science behind levitation?
I've always been most fascinated by the bits of science that might be politely described as 'fringe' – those endeavours that are slightly sneered at by other scientists; the research that sparks argument and derision. If the history of scientific advance tells us anything, it's that those are the areas where novelty and progress spring from. I mean, clearly lots of it is nonsense, and levitation is one of those things that seemingly everyone, scientifically inclined or otherwise, has both a clear idea of, and a strong sense that it's solely the domain of illusions and trickery. That made it very appealing to me because I knew that there was some stuff out there that would really surprise people.

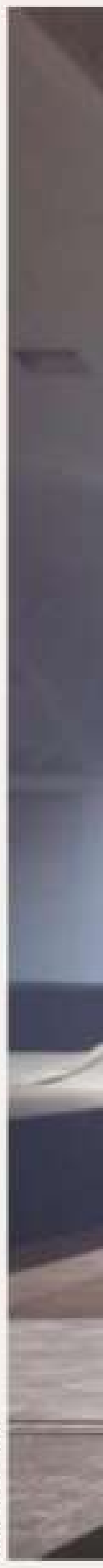
Throughout the special you speak to experts and YouTube creators to learn more about the world of levitation. What were you most surprised to discover about its current and future applications?
Truthfully I went into this knowing nothing of the applications of levitation – I just thought it would be cool! But I quickly learned that the potential applications are huge. From 'acoustic tweezers' which might allow the precise delivery of drugs without the need to open someone up to superconductor innovations, which would revolutionise our energy efficiency.

"Your brain can't really compute what is happening"

During filming, what were the biggest challenges and hurdles you had to overcome to finally achieve your goal of levitation?
It's slightly embarrassing, but the biggest obstacle to getting me up was, simply, that I'm a bit of a unit – 6'5" and 100kg. It would have been a lot easier, for obvious reasons, if I was a little slip of a thing. When we first told the guys who designed and built the hoverboard my weight, there was an audible gasp. Fortunately they managed to create a track and board with sufficient strength to accommodate me!

How did it feel to finally stand on the levitating skateboard, and how would you describe the experience?
It's kind of eerie. It feels a bit like standing on a very unstable skateboard, and your brain can't really compute what is happening. Of course you can't see that there is clear air between you and the track, so your brain assumes that you must be balancing on something, and not locked into a super-strong magnetic field, which is pretty counter-intuitive. It's only really the reactions of everyone else that gives it away – when they're celebrating and telling you that you are levitating!

How would you sum up the journey from preparing for the Edge of Science to seeing the final project?
It's a funny one – the whole way through I was feeling pretty anxious. The idea is that this will be a series and will continue to explore new and exciting and weird science, and I was worried that we'd set ourselves up for a fall by over-promising with this first episode. There were numerous points along the way where we all thought, 'I'm not sure we're going to be able to pull this levitation stunt off'. So when we did, after the initial excitement, I was just flooded with relief!


© BBC Studios

Edwards and Professor Bruce Drinkwater explore the possibilities of acoustic levitation

© BBC Studios

Supercooled science

In the pursuit of defying gravity, Edwards and Colin Furze, a popular YouTuber known for his impressive mechanical creations with over 8.7 million followers, attempt to use superconductors to create a board with the ability to hover along a skate track. At a fundamental level superconductors are materials through which electricity – moving electrons – freely moves without any resistance. However, when dipped in liquid nitrogen and sent into a deep freeze, superconductors produce their own magnetic fields that strongly repel other magnets. By packing 32 individual superconductors inside a futuristic skateboard, adding liquid nitrogen and placing it on a magnetic track, Edwards could finally achieve his levitation goal. When asked what the biggest challenges were when it came to creating the levitation skate ramp, Furze said: "The magnetic sections come in straight pieces and we were trying to make a curved shape, so we didn't want to make the ramp look like a 50p coin. These magnetic track pieces had such powerful magnets that if two were to snap together they would crush you."

© BBC Studios

A combination of freezing temperatures and strong magnets can lead to levitation

Find out how Edwards and his team get on in their mission to beat gravity in the YouTube Original 'The Edge of Science: How to Levitate' on BBC Earth's YouTube channel now!

Edwards attempts to levitate with professional skateboarder Rianne Evans, engineer Dr Oliver de Haas and YouTube inventor Colin Furze

© BBC Studios

Evans' smaller frame makes levitation a slightly easier task

A gene gun is used to alter the DNA of corn cells

© Jurvetson/Flickr

© Getty

How is food genetically modified?

Explore the production of human-made food perfection that takes place in science labs

Words by **Ailsa Harvey**

The majority of what we eat has been sourced from farms and factories which breed and produce especially for the food industry. For centuries humans have been manipulating the outcome and appeal of food sources by changing traits. Selecting the ideal features, people have systematically created many combinations of favourable features in food that would not naturally have occurred.

Genetic modification is one way of ensuring our food has the desired outcome, in a precise and scientific procedure. Previous selective breeding methods relied on luck in some parts of the process, but for this more advanced technique, an organism's DNA structure is cut and modified in a more direct act. This closely controls the outcome and standard of produce.

In order to grow food that is best suited to its environment while incorporating the best traits, scientists look to naturally thriving organisms. Taking the advantageous aspects of their DNA, these are incorporated into mass food production and the creation of crop perfection. Experimenting with new varieties, genetically engineered foods can increase flavour and nutrition, while also protecting the organism against disease. Created in laboratories, scientists play with the combinations of genes in various food sources for an end result that is superior to natural qualities.

But are there any negative impacts of food produced in this way? Over the years many have raised concerns over whether growth and consumption of these foods are bad for our health and that of the environment. Altering nature's course can introduce beneficial aspects to each food source, but it is also important to acknowledge where the method could have downfalls. Some believe modified foods could increase the likelihood of allergic reactions in those who eat them, as well as justifying the creation of more toxic herbicides and pesticides by chemical companies to be used on resistant crops.

Future food

Beginning only as a way to enhance the value of plants, genetic modification techniques are now being explored within the animal food industry. The first animal genetically edited for food quality was salmon. These fish were modified in Canada to adopt the ability to reach full size in only 18 months - half the time it would usually take – while being fed less.

The next steps in genetic modification could be more radical. Pigs and chickens are being worked on to create disease-resistant animals alongside dairy cows without horns and sheep with the ability to produce more offspring.

In terms of crops, being able to grow food that is resistant to harsh environments may be a saviour in preventing famine. Some areas of the globe struggle with an extreme lack of rainfall during their driest seasons, suffering from droughts that hinder their ability to provide food. With climate change likely to only exacerbate these conditions, scientists worldwide are experimenting with the development of drought-tolerant crops in preparation.

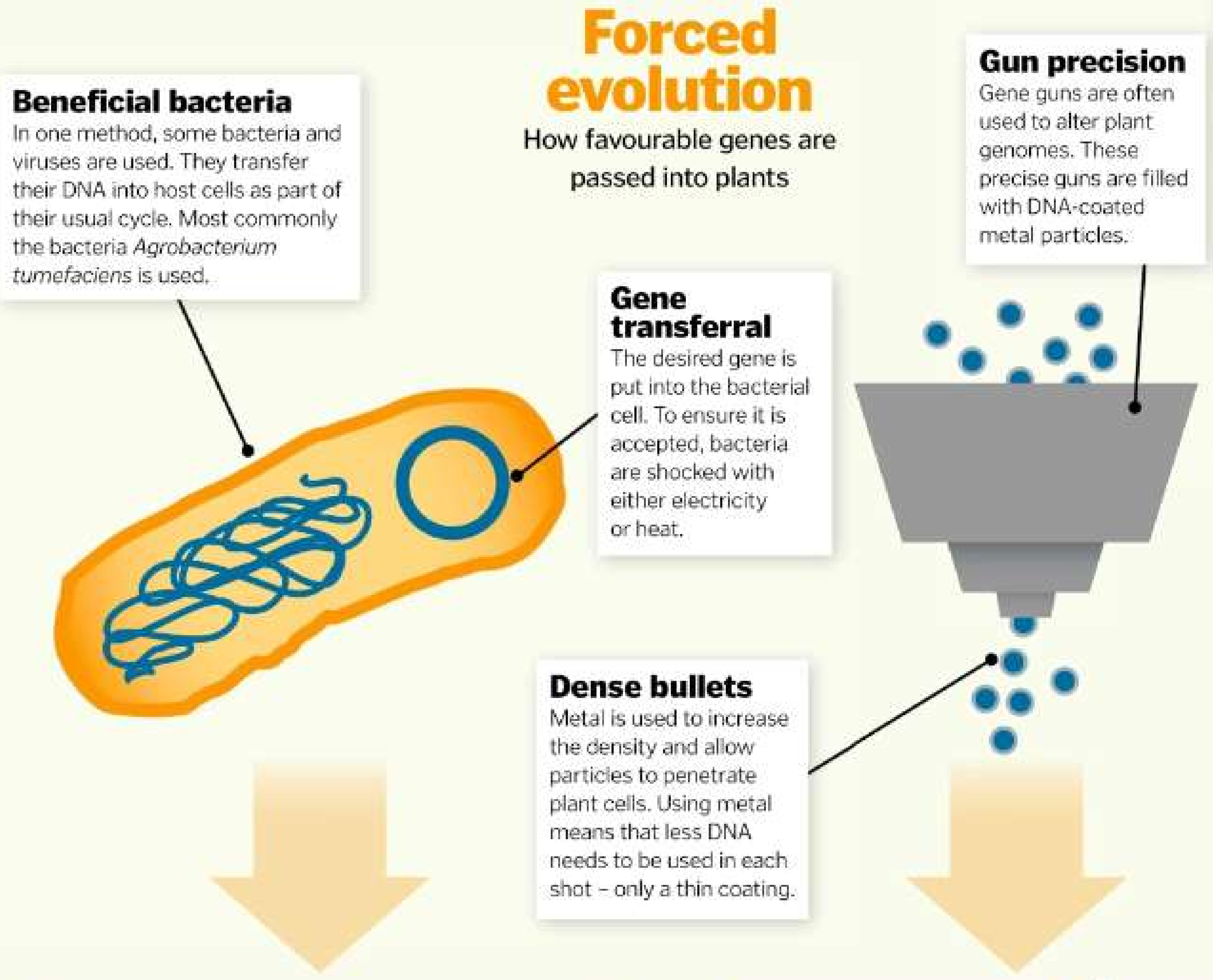
© Getty

Crops such as wheat and soybeans could be engineered to close pores where water is lost

DID YOU KNOW? *The first-ever genetically modified food was the 'Flavr Savr' long-life tomato in 1994*

Forced evolution

How favourable genes are passed into plants

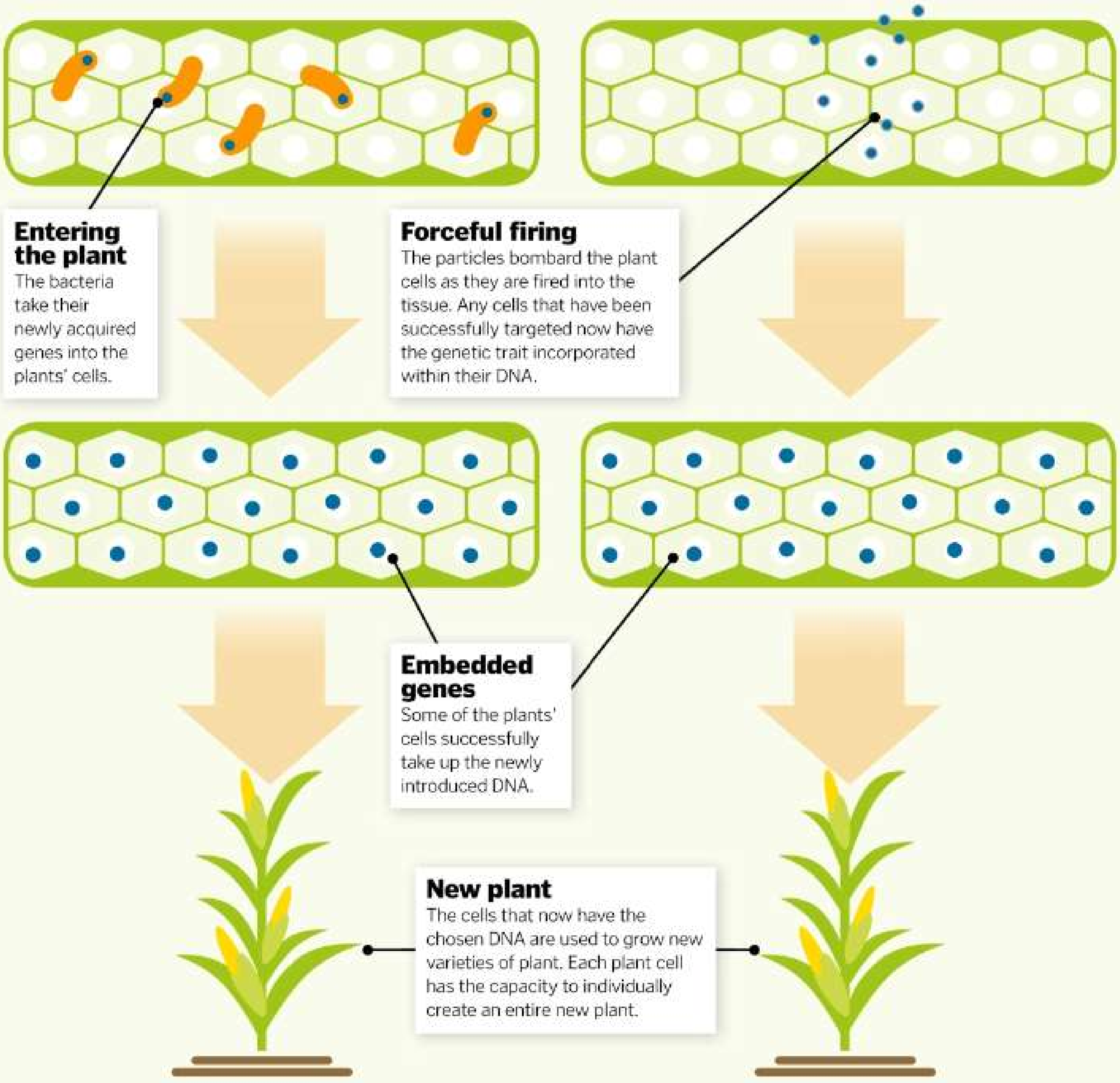


Beneficial bacteria
In one method, some bacteria and viruses are used. They transfer their DNA into host cells as part of their usual cycle. Most commonly the bacteria *Agrobacterium tumefaciens* is used.

Gene transferral
The desired gene is put into the bacterial cell. To ensure it is accepted, bacteria are shocked with either electricity or heat.

Gun precision
Gene guns are often used to alter plant genomes. These precise guns are filled with DNA-coated metal particles.

Dense bullets
Metal is used to increase the density and allow particles to penetrate plant cells. Using metal means that less DNA needs to be used in each shot – only a thin coating.



Entering the plant
The bacteria take their newly acquired genes into the plants' cells.

Forceful firing
The particles bombard the plant cells as they are fired into the tissue. Any cells that have been successfully targeted now have the genetic trait incorporated within their DNA.

Embedded genes
Some of the plants' cells successfully take up the newly introduced DNA.

New plant
The cells that now have the chosen DNA are used to grow new varieties of plant. Each plant cell has the capacity to individually create an entire new plant.

© Getty

Use of the toxic herbicide glyphosate has increased by 1,500% since resistant GM crops were introduced

5 FACTS ABOUT

FICTITIOUS FRUITS BECOMING REALITY

1. **Arctic apple**
Created to resist turning brown, these apples are available in the US. Once the apple is cut, the inside is prevented from changing colour. Those responsible for modifying the apples claim that foods with these qualities will help to reduce food waste.

2. **Peachy strawberries**
Strawberries are being experimented with in order to give them the sweetest taste possible. In a merger between two fruits, some modification is producing strawberries that are peach flavoured.

3. **Disease-resistant bananas**
A common disease in bananas called fusarium wilt has prompted scientists to develop a batch of resistant bananas. This will ensure that these bananas can all stay healthy for consumption.

4. **Spicy tomatoes**
Some Brazilian scientists are testing the possibility of hot tomatoes with their spicy selection. Tomatoes have some of the same genes which produce spicy chemicals as chillies, but they are dormant. Altering this part of the genome, tomatoes could be used as more accessible chillies.

5. **Rainbow papaya**
The rainbow papaya was modified to make papaya production more efficient. Papaya farms across Hawaii were suffering from a loss of a huge number of their fruit to the ringspot disease. Since commercialisation in 1998, the rainbow papaya is claimed to have saved the industry in Hawaii.

TURNING LEFT
CONCEPT-i RIDE

INCREDIBLE BREAKTHROUGHS OF 2020

From AR contact lenses to the robot Olympics, watch out for these potential advances in science and technology this year

Words by **Ailsa Harvey**

BOEING
STARLINER

© Getty

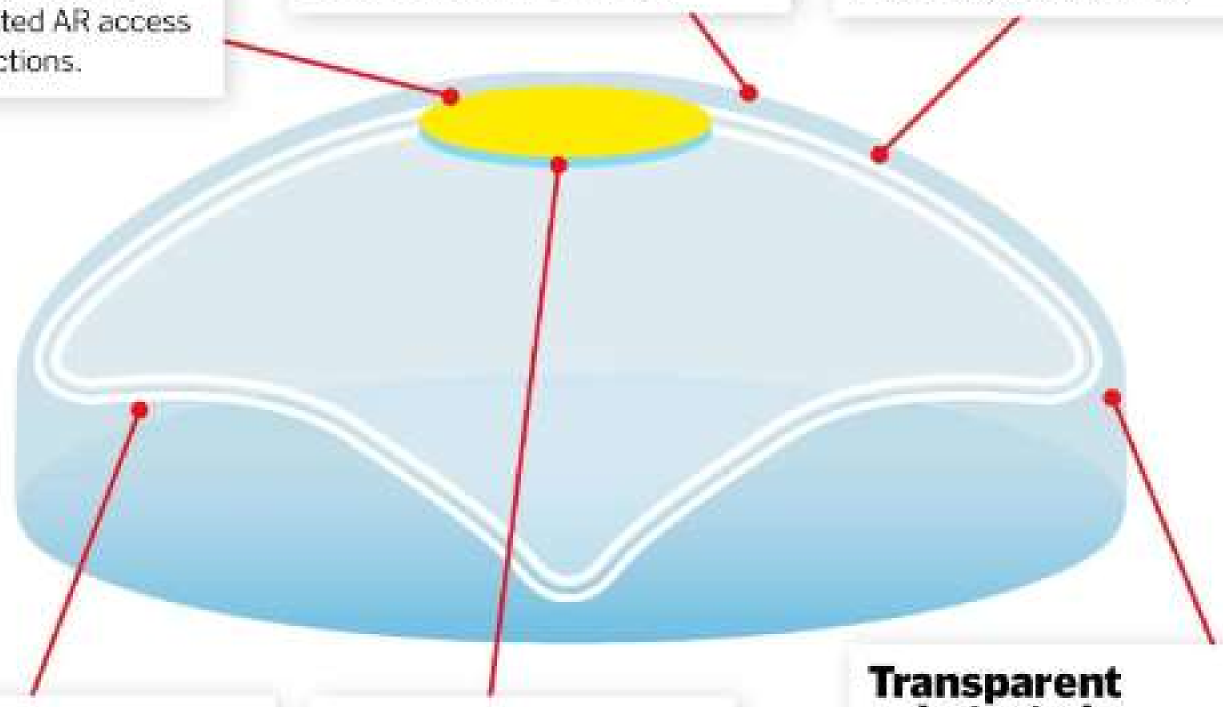
AR CONTACT LENSES

Forget having your eyes glued to your phone, soon it could be a part of you

Contact lenses are great for enhancing vision while remaining discrete. But imagine if they added more to what you saw than clarity. Samsung has invented smart AR contact lenses with built-in hidden cameras that enable you to extend the information you receive when wearing them. With Samsung's lenses now patent-approved, smartphone use as we know it could soon change.

The lenses will allow the wearer to record videos from their point of view, take pictures and control devices with their eyes using embedded motion sensors. Commands could be controlled using eye motions, such as blinking to take a photo. Additionally, photos from other smart devices could be beamed into the wearer's eyes, overlaying their view of the real world.

Unlike similar glasses designs, this contact lens will imbue the wearer with the sense that they're controlling these digital abilities with their mind, while the device also gives them an increased angle of view.



Display unit
The display unit receives information from across the contact lens and projects images into the eye. It can move with the pupil's movement for unlimited AR access in all directions.

Encapsulation layer
This outer layer encloses the contents, and is designed to comfortably fit the eyes. The encapsulation layer includes the standard materials used in regular contacts, such as hydrogel.

Passivation layer
This layer is sandwiched between the device and the lens to act as a shield and keep the lens from getting damaged, as well as acting as an electrical insulator for the device's contents.

Device layer
This is where the important AR tech is stored, including tiny cameras, antennae to connect to outside devices and motion sensors.

Wiring portion
Surrounding the display unit, the electrical wires bring all collected information to the front of vision, creating the overall view and experience.

Transparent substrate layer
This is covered in an array of tightly packed microlenses, more densely packed over the centre display unit, creating higher resolution images.

REMOTE AR AVATARS

How can communicating with projected avatars of people anywhere in the world better connect us?

© Getty

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FILLING A ROOM

Avatar Chat by Magic Leap is one of the first examples. When connected to the platform you can invite your friends over, and it appears as though they are in the room – or their avatar is. While all people can see the group of avatars, soon you could also be able to see the room you enter when you virtually visit friends' houses. The technology could tackle the issue of loneliness for those away from their loved ones.

TEACHING

These platforms could be used to provide alternative teaching methods. Students can interact with tutors, and training staff could conduct training sessions with groups spread across the globe. The current technology in Avatar Chat emulates head position, eye movements and body language, creating the best medium to express what is being taught through long-distance communication.

EMERGENCY AID

Where specialist knowledge is required, assistance is often needed quickly. With fast-connecting technology, expert opinion could be applied in an instant. With AR eyewear and avatar technology, experts could instruct others on what to do by looking at the scene and using avatar gestures to demonstrate actions. This could include medical advice or the engineering of household appliances.

DRONE DELIVERIES

In an attempt to make home deliveries even speedier for lightweight items, drones could soon be dropping off your orders to your door. One company that aims to provide this option around the world in 2020 is Amazon, with its Amazon Air service.

As close as you can get to instant delivery, the drones will get your parcel to you in half an hour or less. Through 'sense and avoid' technology, the drones will steer away from obstacles to deliver safely.

Amazon's delivery drones will have a weight limit of about two kilograms

© Amazon

WORLDWIDE INTERNET BALLOONS

The internet has enhanced our communication and connection to global affairs. But what about those remote areas where even in the 21st century, people are yet to have access to the internet?

As part of a Google-run project, a network of balloons is set to be installed in the sky to improve connectivity everywhere. This includes extremely rural areas where people are isolated, as well as places impacted by natural disasters where the internet is lost.

How are they going to do this? Filled with helium, the 15-metre-wide solar-powered structures will serve their role as they slowly drift across the stratosphere. Equipped with antennae, each balloon provides 5,180 square kilometres of land below with internet access. Attached to the bottom of the balloon is the equipment: the antennae transceive data, the solar panels power the equipment, a capsule contains the balloon's electronics and a parachute is ready to be deployed at the end of the balloon's flight.

Once in position, the balloons aren't fixed in place. They can be manoeuvred by technicians and their location is tracked by Air Traffic Control using GPS. After an 8.0 magnitude earthquake struck Peru in 2019, 20,000 people used this service in 48 hours.

© Loon

Balloons last for over 100 days in the sky before landing on Earth in a slow, controlled descent

TECHNOLOGY TRENDS IN MEDICINE

How better technology can lead to better health

© Getty

WEARABLE TECH

These days you can tell a lot about your own fitness without having to attend a doctor's appointment. Many of us are willing to strap monitors and sensors to our bodies in everyday life in the form of smart watches – but these wearable tech trends are set to evolve from fitness trackers to real-time clinical monitors in 2020. For life-threatening cases such as cardiac diseases, medical practitioners could be automatically alerted to any worrying changes.

© Getty

3D PRINTING

Being able to produce a physical object from a digital file is starting to transform aspects of the medical industry. From transplanting printed organs to improving an individual's quality of life through prosthetics, the use of 3D printers in medicine will continue to rapidly expand. Surgical tools are also becoming more personalised to aid medical professionals in precise and intricate procedures.

© Shutterstock

DIGITAL TWINS

With the invention of digital twin technology, the medical world is able to further improve accuracy and accelerate research by incorporating it into healthcare. The technology serves to create digital replicas and simulations of physical objects, and even people, allowing procedures to be practised without inflicting harm.

Soon digital twins may be used to replicate entire hospitals as well as individual cases to see how changes within the hospital could impact patients and identify any issues before they arise in real life.

© Shutterstock

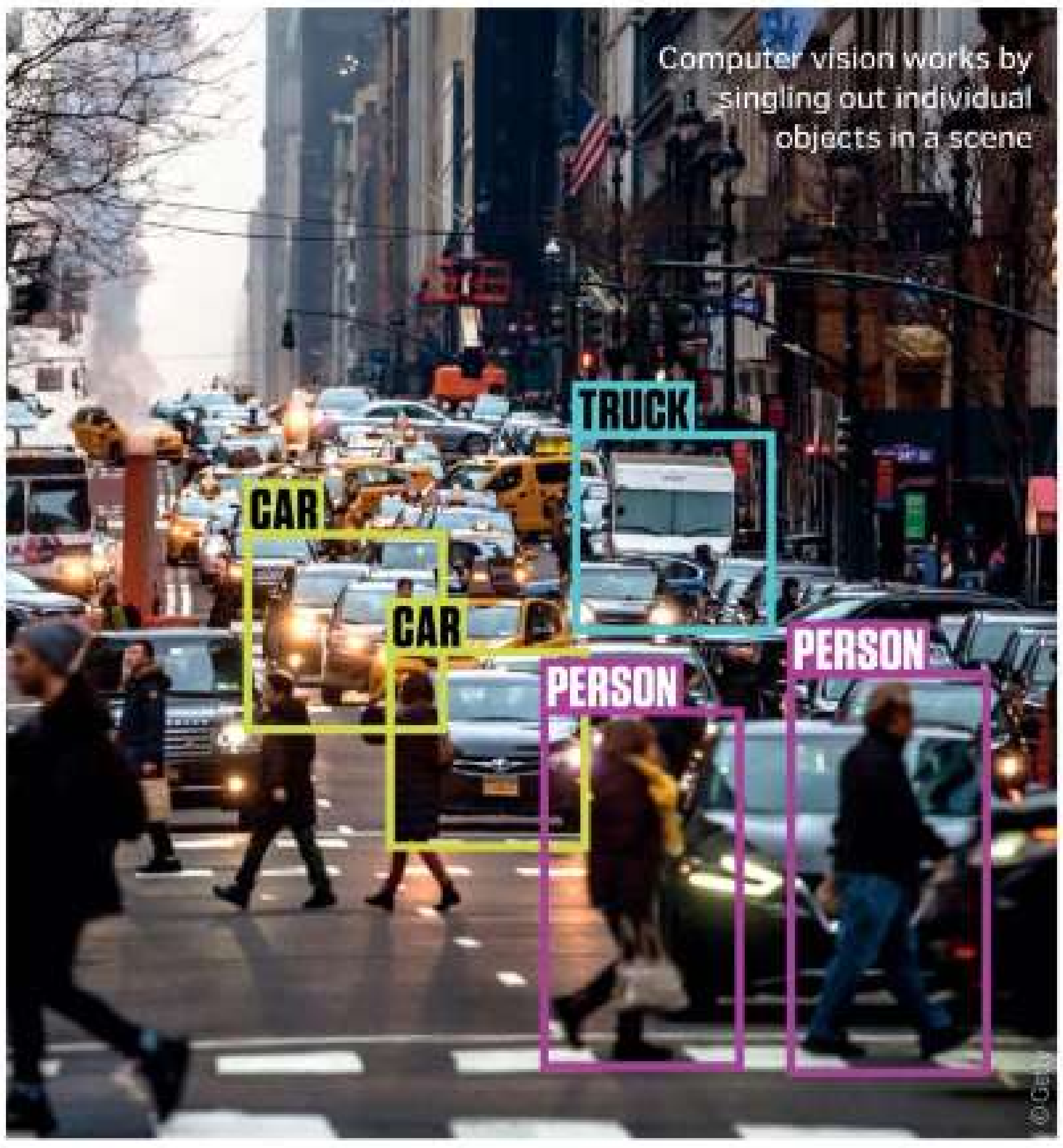
MACHINE LEARNING

Artificial intelligence (AI) is continuing to improve. But what if this led to machines replacing doctors and nurses altogether? Virtual nursing is one way that AI is taking over in the world of medicine. In some cases, machine learning chatbots are engaging with patients more frequently than human nurses are.

SMART CAMERA VISION SYSTEM

As we head into 2020, more cameras should be able to understand what they are seeing rather than acting as a display screen. This technology is called computer vision, and it can be used to install safety systems through artificial intelligence.

The computers work by assembling visual images like a puzzle. By identifying the edges, shape and where the objects sit in the field of vision, the camera's images are taken through a filtering system before determining what it is looking at. Upcoming uses for this technology include installation into self-driving cars to work as a replacement a human driver's eyes, interpreting objects and any possible dangers. Computer vision could prove to be a key progression in technology for those who are visually impaired. By incorporating natural language processing, if computers can understand what they see, they can translate these images into words, serving almost as eyes for the blind.



Computer vision works by singling out individual objects in a scene

© Getty

MORE INTELLIGENT CARS

Cars could become a real connective companion

CAR COMPANION

Due to be launched in 2020, Toyota's car intelligence technology could see cars looking out for us on much deeper levels. AI could transform our driving experience by supporting our emotional wellbeing in the car. Toyota's Concept-i will analyse the driver's body language, speech tone and use of language. Getting to know personal preferences, the car could then respond in ways it calculates to improve mood. At a Tokyo motor show, the car demonstrated how it could cool or warm the car temperature, release pleasant fragrances, change the atmosphere through interior lighting and even begin a conversation.

TURNING LEFT
CONCEPT-i RIDE

The Toyota Concept-i will be launched for public trials in 2020 © Tokumeigakarinoaoshima

KEYLESS CARS

The mad dash in search of your car keys as you leave the house could be unnecessary with new car unlocking technology. Safe new ways to unlock your vehicle are emerging with facial recognition and fingerprint technology. While cars with these features are already available, a 2020 emergence could see these properties starting to become the norm. One new concept car, the Karma SC2, has received major funding for its new biometric features – signalling that this could be the new future for car access.

© Getty

Fingerprint security works by turning scans into a digitalised code. This code needs to be re-matched for access

2020 PREDICTIONS PROVED WRONG

We are always imagining what the future will hold, but these come with varying accuracy

"WE WILL LIVE IN FLYING HOUSES"

This prediction came from inventor and science writer Arthur C Clarke. In 1966 he guessed that houses were too dull for the days of 2020. Flying houses would be able to transport you without having to leave your house, and whole cities could migrate somewhere warmer for colder seasons. Unfortunately, today's houses are still firmly on the ground, and will most likely be there for a while.

"MAIL WILL BE SENT VIA ROCKETS"

Most of us may still be using standard post offices, but a successful delivery by missile was once made in 1959. That year, 3,000 letters were sent to political figures via rocket. These successes were enough to make postmaster general Arthur E Summerfield predict that this would become a common affair.

"TUBES WILL REPLACE ROADS"

In 1957 an article was published in *Popular Mechanics* with its prediction that America's roads would be replaced by a tube system. Requiring you to drive only from your house to the tube, the more efficient system would power you to your destination.

"WE'LL VOTE FROM HOME"

As a 1997 prediction for 2020, Peter Schwartz and Peter Leyden believed e-voting would be a reality. With no need to trek to your nearest polling station, voting could take place at home. However, this is still deemed too risky and unreliable.

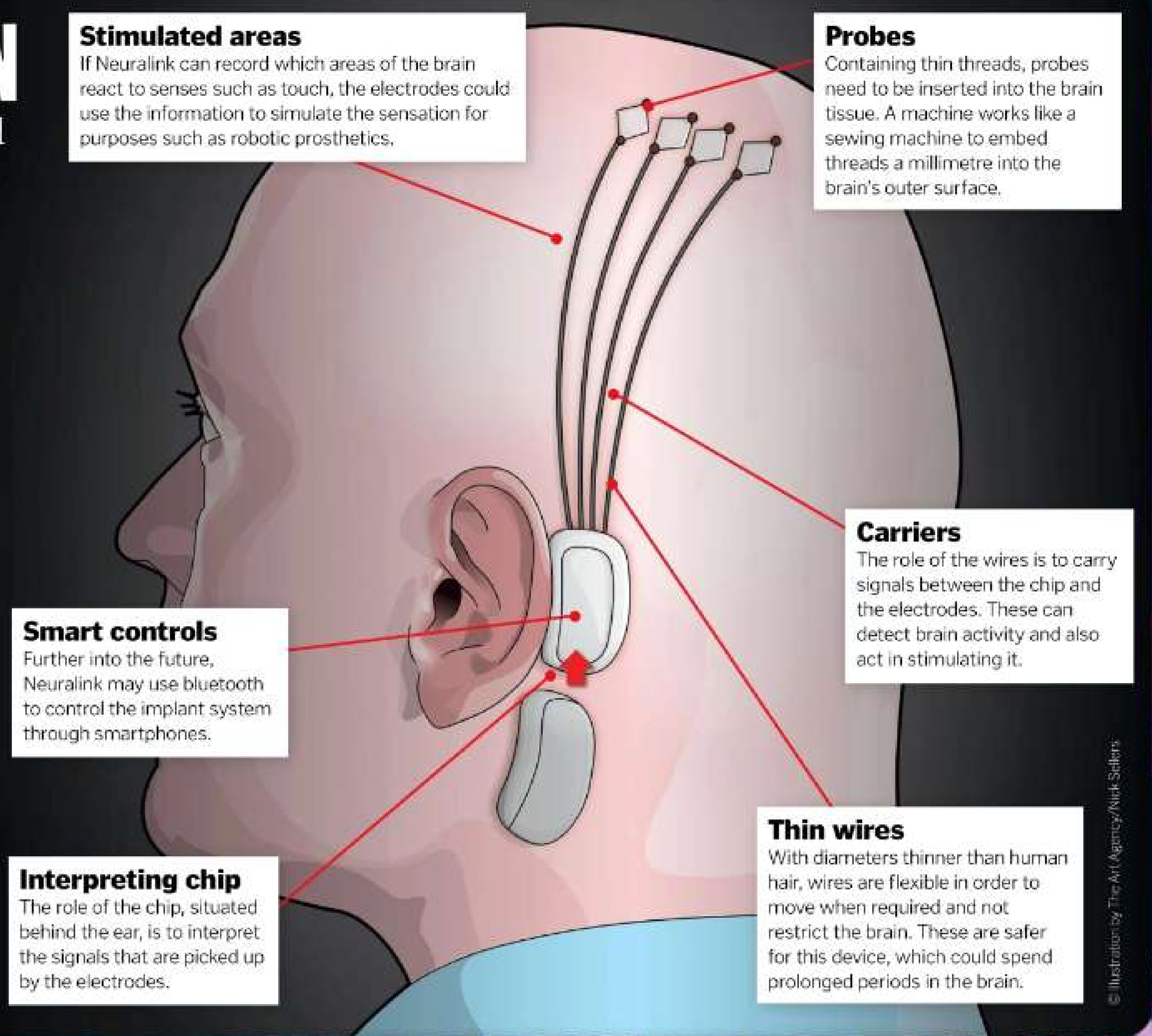
AI IN THE BRAIN

Discover the implant that could reduce neurological issues and even connect AI to the brain

We now live in a world where many of us are glued to our mobile phones – but what if you were literally connected to yours? A proposed brain implant called Neuralink aims to connect the human brain with artificial intelligence through a smartphone application.

Serving not only as a way to enhance human ability with computerised capabilities, the chip should also record deep-brain electrical activity in order to understand and improve numerous cognitive issues. The device is claimed to be able to assist stroke victims with a memory-boost feature, as well as helping those experiencing various forms of paralysis.

The surgical procedure required to put one in place involves small holes being drilled into the skull by a robot for the chip to plug into. Human trials for this device are planned to start by the end of 2020.



Stimulated areas
If Neuralink can record which areas of the brain react to senses such as touch, the electrodes could use the information to simulate the sensation for purposes such as robotic prosthetics.

Probes
Containing thin threads, probes need to be inserted into the brain tissue. A machine works like a sewing machine to embed threads a millimetre into the brain's outer surface.

Carriers
The role of the wires is to carry signals between the chip and the electrodes. These can detect brain activity and also act in stimulating it.

Smart controls
Further into the future, Neuralink may use bluetooth to control the implant system through smartphones.

Interpreting chip
The role of the chip, situated behind the ear, is to interpret the signals that are picked up by the electrodes.

Thin wires
With diameters thinner than human hair, wires are flexible in order to move when required and not restrict the brain. These are safer for this device, which could spend prolonged periods in the brain.

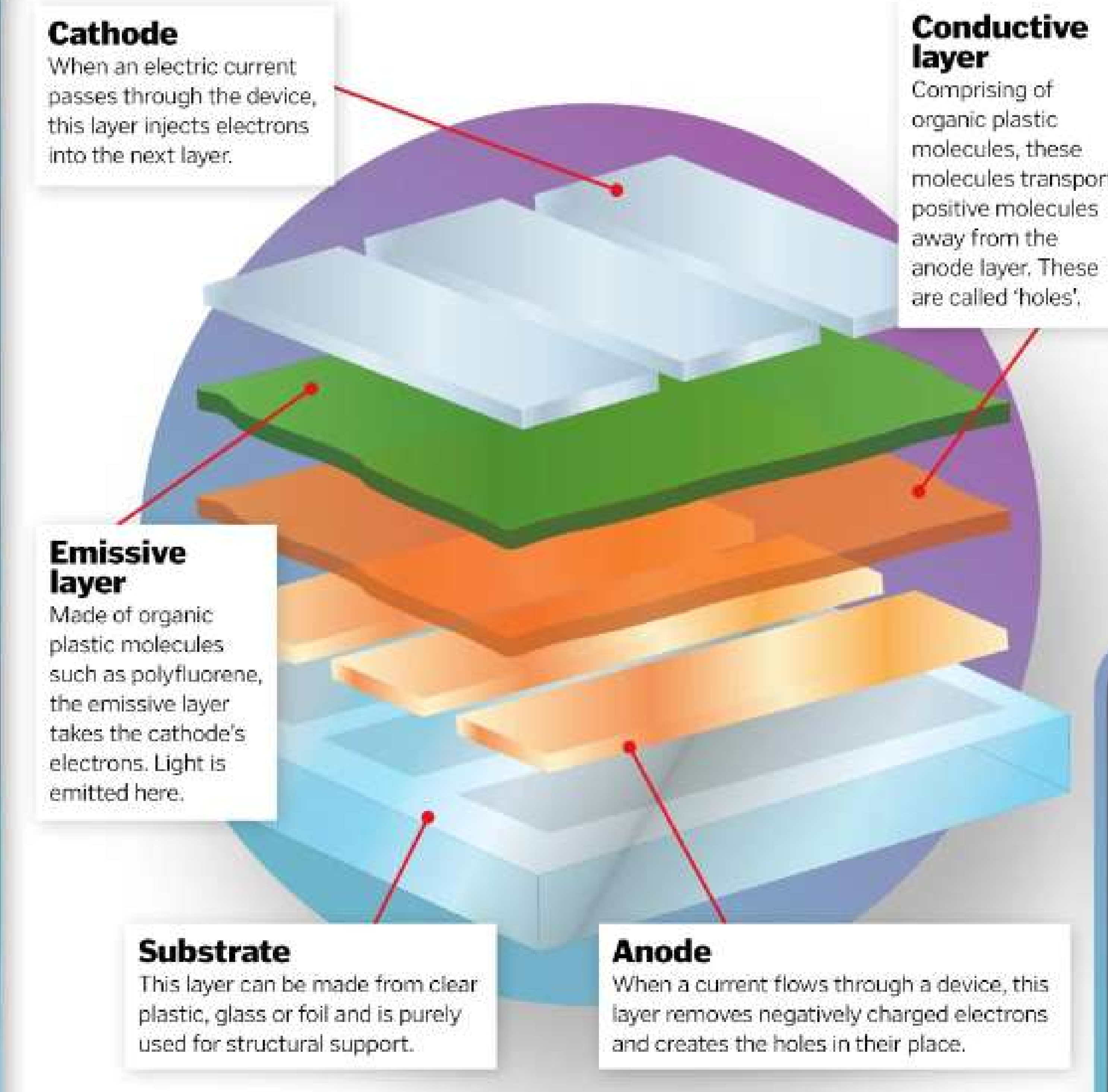
© Illustration by The Art Agency/Nick Sellers

SMARTER SCREENS

OLEDs could mean bendable displays

The number of screens we watch in our lives is on the rise as technology is delving further into the digital world. While the content we can stream onto screens is improving, so are the screens themselves. Most homes currently have LCD screens, but predictions for 2020 see the takeover of OLED. So what are OLEDs, and how much difference can a screen's properties make?

OLED stands for organic light-emitting diode, and is made of a material that glows when hit with electricity. The current strength sent to different sections of the screen determines how much light is emitted. The ability to have some of the screen exposed to high currents and other sections with no current at all enables a perfect black to be used for better contrast – a feature not possible in many modern-day TVs. Transforming the screens we may be familiar with today, OLED screens hold the possibility to become flexible and foldable, bringing new opportunities for smartphone and television design. We could soon have smartphones with foldable faces, or even entire walls covered in these innovative screens.



Cathode
When an electric current passes through the device, this layer injects electrons into the next layer.

Conductive layer
Comprising of organic plastic molecules, these molecules transport positive molecules away from the anode layer. These are called 'holes'.

Emissive layer
Made of organic plastic molecules such as polyfluorene, the emissive layer takes the cathode's electrons. Light is emitted here.

Substrate
This layer can be made from clear plastic, glass or foil and is purely used for structural support.

Anode
When a current flows through a device, this layer removes negatively charged electrons and creates the holes in their place.

With OLED technology you could open your phone screen like a book

© Getty

INTELLIGENT FOOD LABELS

When you go to the supermarket to pick up your food shopping, you may spend a lot of time searching for expiry dates. 2020 could transform our food labelling system, with more useful features such as colour-changing tags that represent the stage of food decay or labels that are able to tell more information than just the price when scanned. Time temperature indicators are tags that use temperature levels over time to communicate the stage of food decay with the consumer. By determining the edibility of food using the colour code, these labels work more accurately than printed best before dates. These scientific labels are thought to reduce the amount of food unnecessarily thrown out before spoiling.

Another type of intelligent labelling involves RFID tags. For this to work, labels are embedded with a tiny antenna. When activated by radio waves in the scanner, the tag responds, sending a range of details about the product.

Mettler - Toledo GmbH
Intelligent Scale

RFID labels can show expiry date, weight and price in one scan

© Getty

BEGINNING COMMERCIAL SPACE TRIPS

Over 50 companies are researching the commercialisation of space trips, and NASA has worked with ten to create 14 facilities on the International Space Station. These steps are in preparation for bringing tourists to space in 2020. SpaceX and Boeing have both built vehicles especially for private commercial use to operate as taxis leaving our planet.

Thought to cost around £27,500 a night, the holiday won't be a cheap one, as the 30-day excursion could leave passengers with a fee of around £47 million. Robyn Gatens, deputy director of the International Space Station, announced that they aim to conduct two short commercial space missions a year to begin with; an opportunity that serves as a huge landmark for the future of space travel.

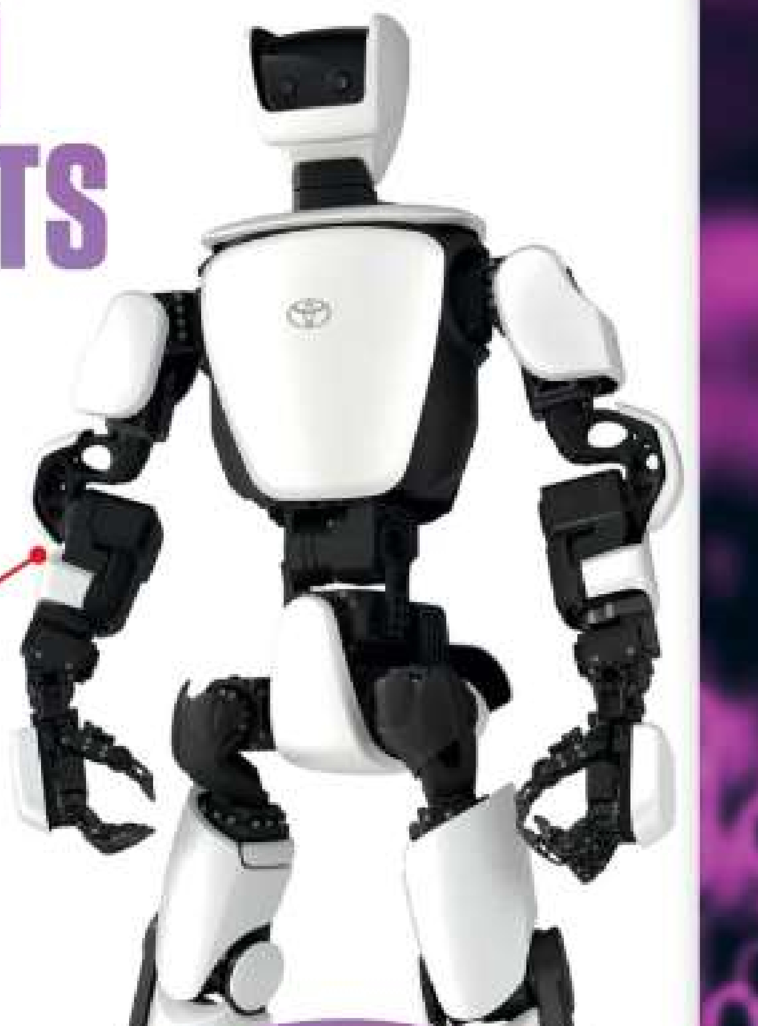
BOEING
STARLINER

Boeing is working on a space ship called CST-100 Starliner

© Boeing

MEET THE 2020 OLYMPIC ROBOTS

Demonstrating the potential for future robot jobs, these helpers will be of assistance in Tokyo throughout the games

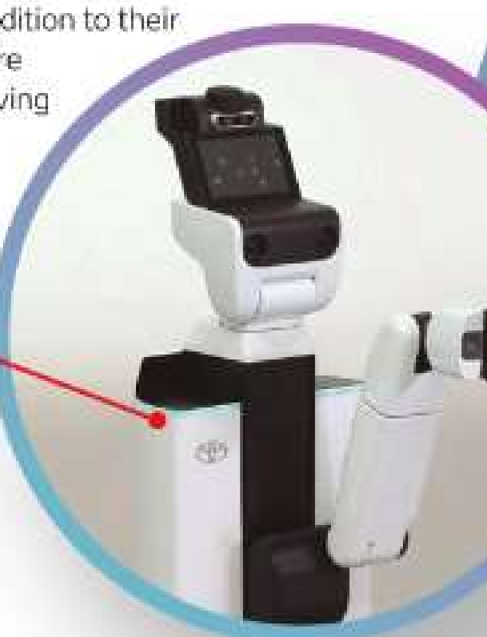


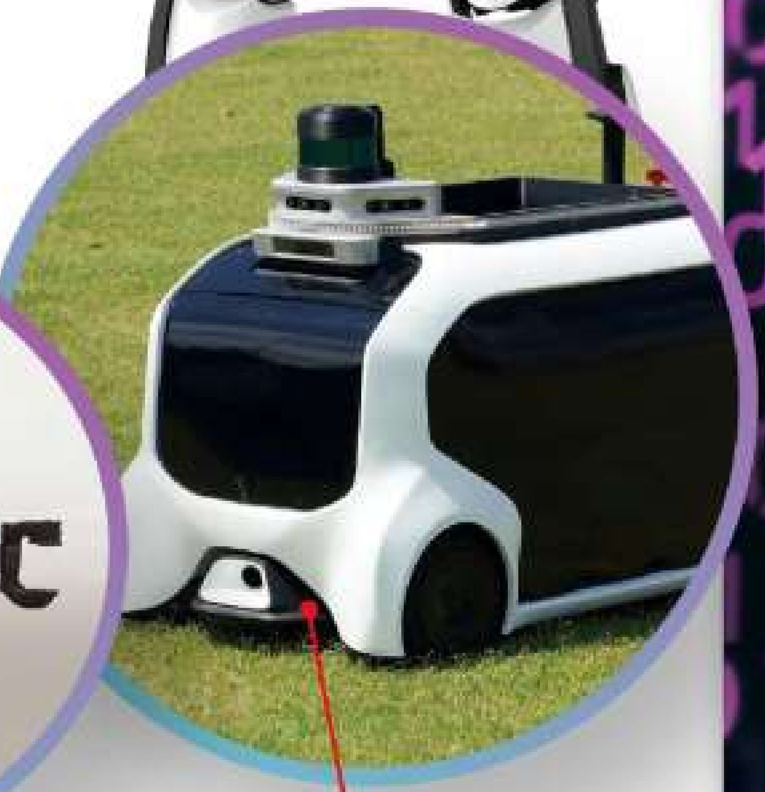
Humanoid

This robot benefits those who are unable to attend the games by interacting with athletes. Replicating sound, images and force-feedback, these robots let people communicate with athletes in Tokyo, and if things go well, even give them a high-five.

Human support

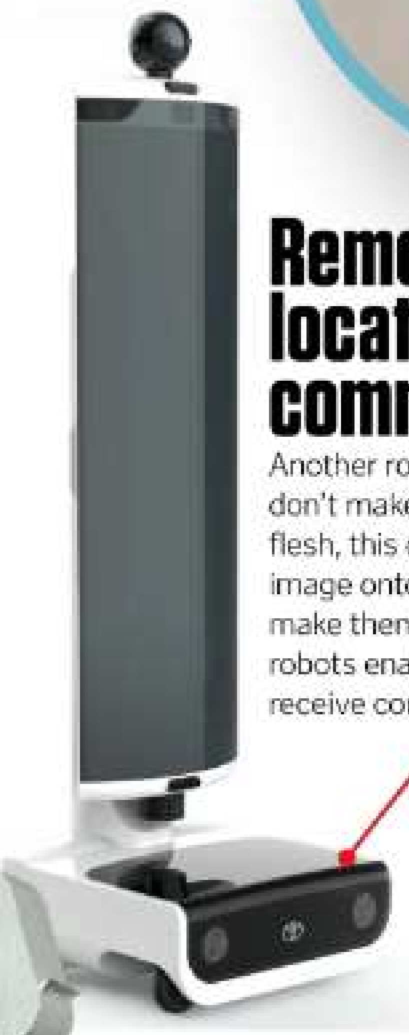
Assisting members of the audience, these mobile robots guide them to the seats they can access. Using their arms they can also bring spectators meals and other items as a complementary addition to their experience. They are expected to be serving over 1,000 people during both the Olympic and Paralympic games.





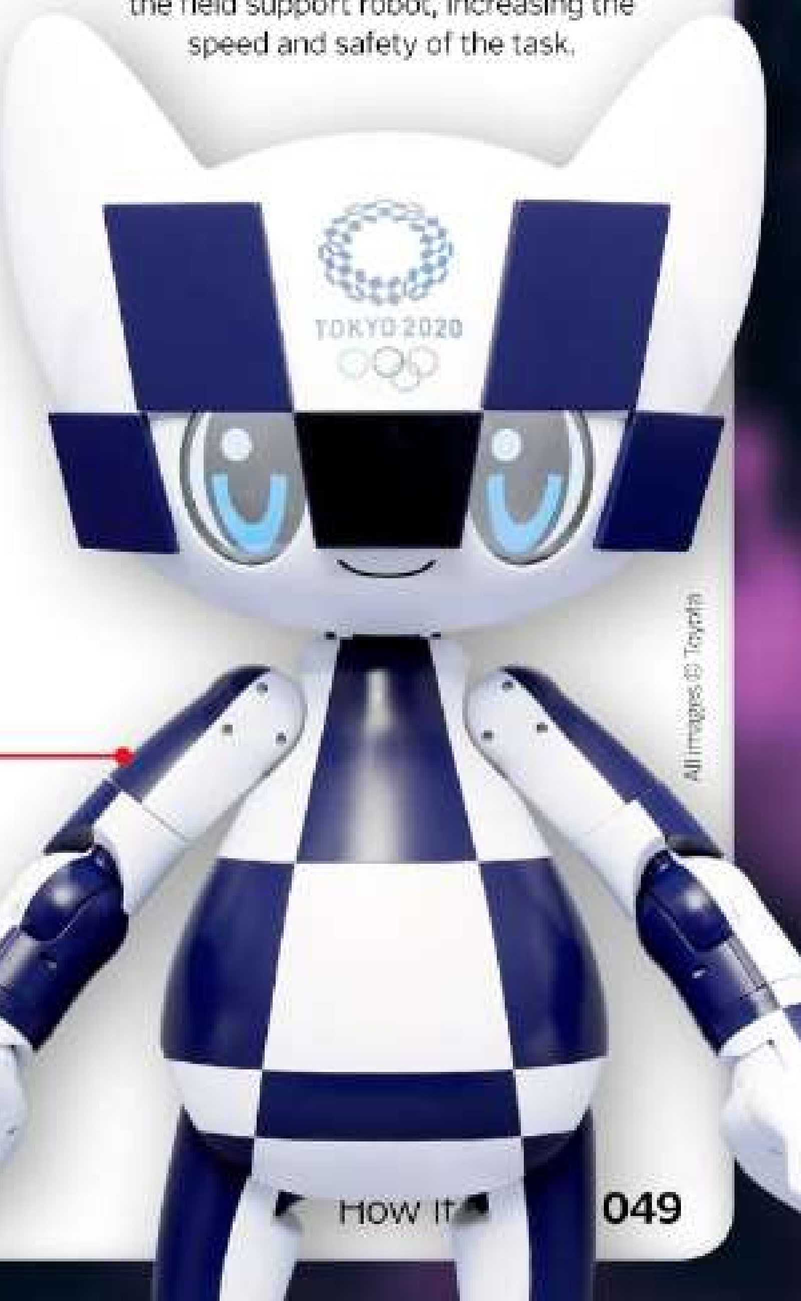
Field support

For throwing events such as javelin, less staff will be needed to collect equipment from the middle of fields. This is a job for the field support robot, increasing the speed and safety of the task.



Remote location communication

Another robot built for those who don't make it to the games in the flesh, this one projects their image onto a lifesize display. To make them feel present, the robots enable them to send and receive communication.



Mini mascot

Tokyo is aiming to make this Olympics the most technologically advanced of all time. They are also catering for the children who attend with their mascot robots. These will be able to interact with them, recognising people through built-in cameras on their heads and responding with expressions.

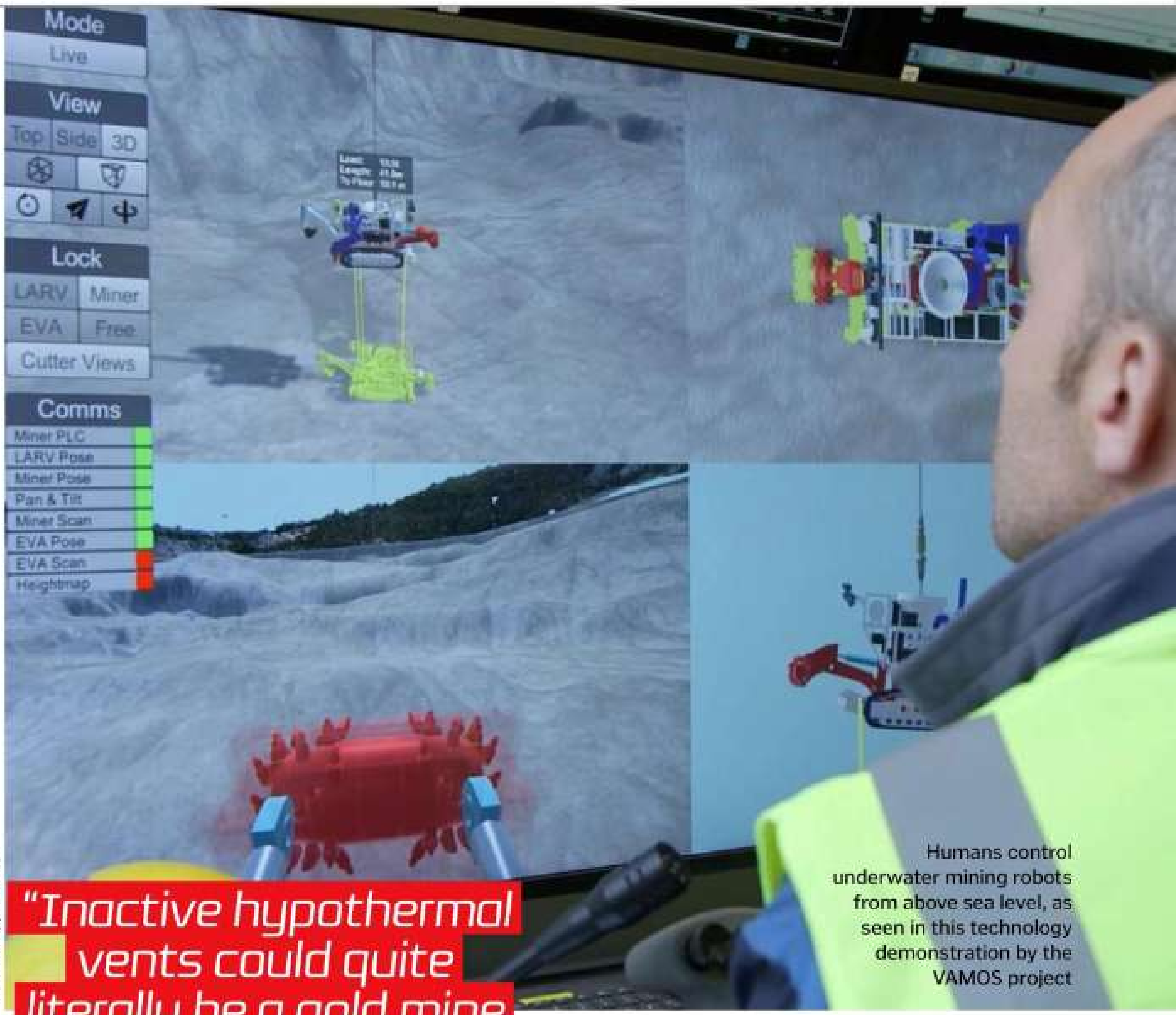
All images © Toyota

Deep-sea MINING

Discover how digging in the ocean depths can reveal buried treasure – but at what cost?

Words by **Scott Dutfield**

DID YOU KNOW? *There's a 65,000-kilometre tectonic boundary wrapped around the world called the mid-ocean ridge*



Humans control underwater mining robots from above sea level, as seen in this technology demonstration by the VAMOS project

© Damen Shipyard Group

What lies beneath the world's oceans is one of nature's biggest mysteries, with most of our planet's seabed still unexplored, yet to be mapped by sonar technology. Since the 1960s researchers have wondered about the possibilities of extracting valuable resources from the deep blue. Now, around 60 years later, we might be on the cusp of deep-sea mining becoming a reality.

But what could be so valuable at the bottom of the ocean? Much like the gold found on a sunken ship, the prospect of finding coveted minerals and metals has spearheaded a movement into the creation of subsea miners. Although shallow seabed mining is currently in operation in areas of the Pacific and the Indian Oceans, deep-sea mining is a venture not yet embarked upon. However, mining companies such as Nautilus Minerals are hoping to be the first to commercially harvest marine-made metals.

Found scattered around the ocean floor, and particularly abundant in the waters surrounding Papua New Guinea, once-smoking vents called polymetallic massive sulphides are the target for deep-sea miners. Containing valuable metals and minerals such as cobalt, copper, gold and silver, these inactive hydrothermal vents could quite literally be a gold mine for obtaining lucrative elements.

On land, diggers and mining equipment are typically operated by manned machinery. But even with the world's most advanced technology, humans aren't yet commercially able to dive to great depths. So how does Nautilus Minerals, for example, expect to exploit mineral havens sitting 500 to 5,000 metres below the surface? Quite simply, keep the humans above water and let the robots go to work.

Using umbilical cord-like attachments, mammoth mining vehicles are connected to the production support vessel bobbing on the ocean's surface. From there the equipment can be lowered into the water and manoeuvred remotely. What these puppeteers are piloting is a team of three separate vehicles, each with a different role to ensure success. Leading the deep-sea dive is the Auxiliary Cutter, which uses its mining drum to create 'benches', flat surfaces on the seafloor for other machinery to work on. Once the groundwork is complete, the Bulk Cutter moves in to do the heavy lifting and grinds away at the metallic crust. This freshly ground seabed remains in expelled piles by the Bulk Cutter until the collecting machine comes along to suck up the goods and send them up through another pipe connecting these subsea machines and the production support vessel above, where it will be processed and shipped to land.

> "Inactive hypothermal vents could quite literally be a gold mine for obtaining lucrative elements"

Much like the mining that occurs on land, subsea excavations come at a cost to their surrounding environment. One of the biggest concerns of environmentalists is the removal of key species in the marine ecosystems. Many different benthic (deep ocean) species call potential mining sites home: species such as sponges, corals and starfish, which play a vital role in maintaining a balanced ecosystem. By removing these key players, the effects on the environment could be potentially devastating for marine life. Due to the complexity of ocean ecosystems, scientists have not yet been able to precisely predict the negative effects deep-sea mining could have. However, an impressive 26-year-long study conducted by the National Oceanography Centre (NOC), suggests a dismal future. After investigating an area of ocean floor 4,000 metres deep off the coast of Peru that had been exposed to a mining simulation of metal-bearing nodules, it found that track marks were still visible 26 years on. And most, if not all of the marine life from the area had not returned.

Although deep-sea mining is not yet happening on an industrial scale, licenses to do so have been issued to a handful of countries by the International Sea Authority, covering a combined oceanic area of over 1.3 million square kilometres.

Seafloor hoover

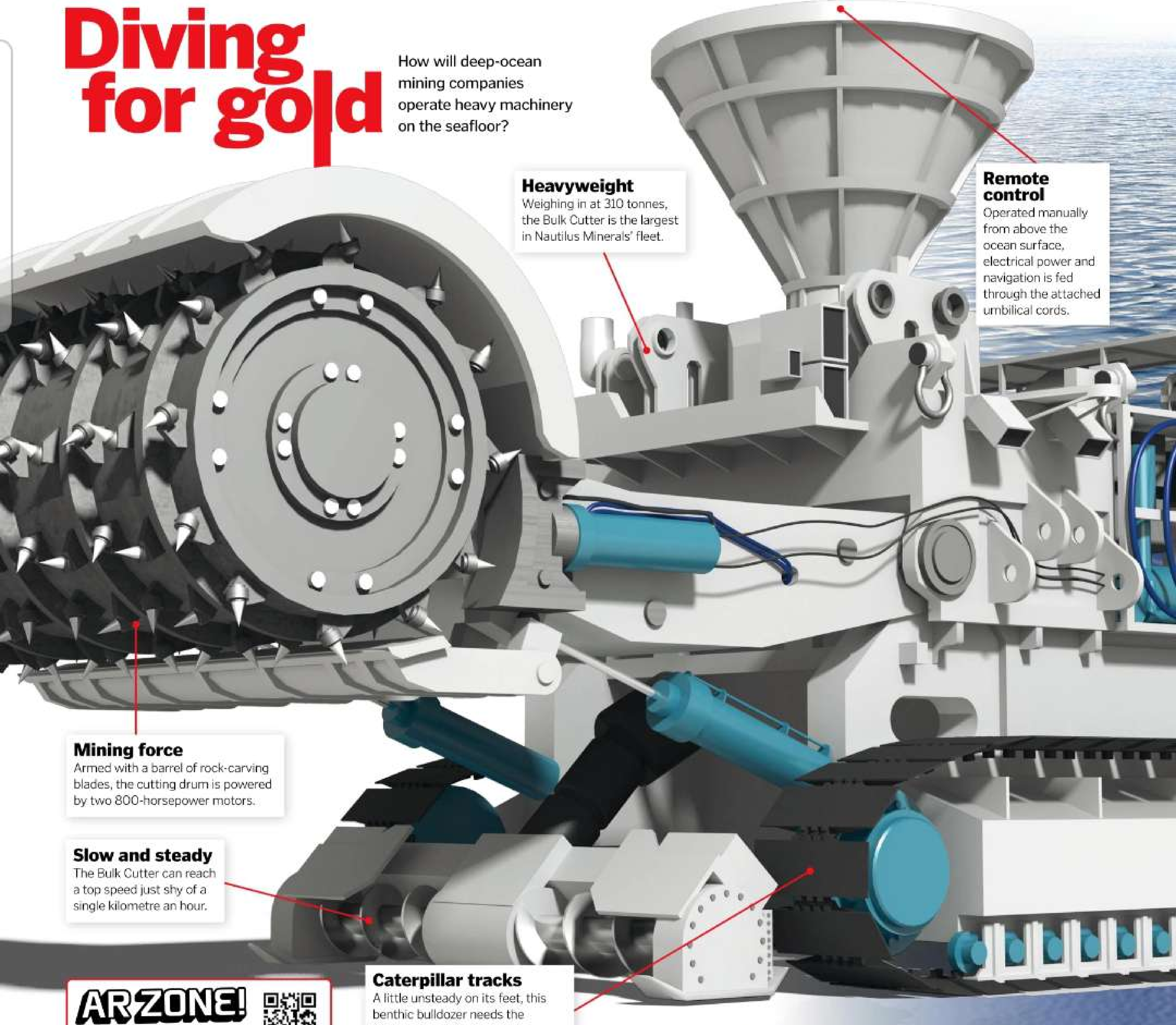
In what appears to be a cross between a deep-sea miner and a Roomba, EU-funded projects such as Blue Nodule have designed a method of mining that sweeps along the ocean floor collecting copper and manganese-rich polymetallic nodules. Much in the same way as the machines by Nautilus, this umbilical cord-bound miner crawls the seafloor, hoovering up nodules as it goes. With the ability to descend to depths of between 3,000 and 6,000 metres, these autonomous crawlers are capable of processing the nodules on the seabed before sending them up to the base ship above.

Precious metals lie deep below

© Alamy

Diving for gold

How will deep-ocean mining companies operate heavy machinery on the seafloor?



Heavyweight
Weighing in at 310 tonnes, the Bulk Cutter is the largest in Nautilus Minerals' fleet.

Remote control
Operated manually from above the ocean surface, electrical power and navigation is fed through the attached umbilical cords.

Mining force
Armed with a barrel of rock-carving blades, the cutting drum is powered by two 800-horsepower motors.

Slow and steady
The Bulk Cutter can reach a top speed just shy of a single kilometre an hour.

Caterpillar tracks
A little unsteady on its feet, this benthic bulldozer needs the assistance of the Auxiliary Cutter to carve flat tracks on the seafloor.

AR ZONE! SCAN HERE

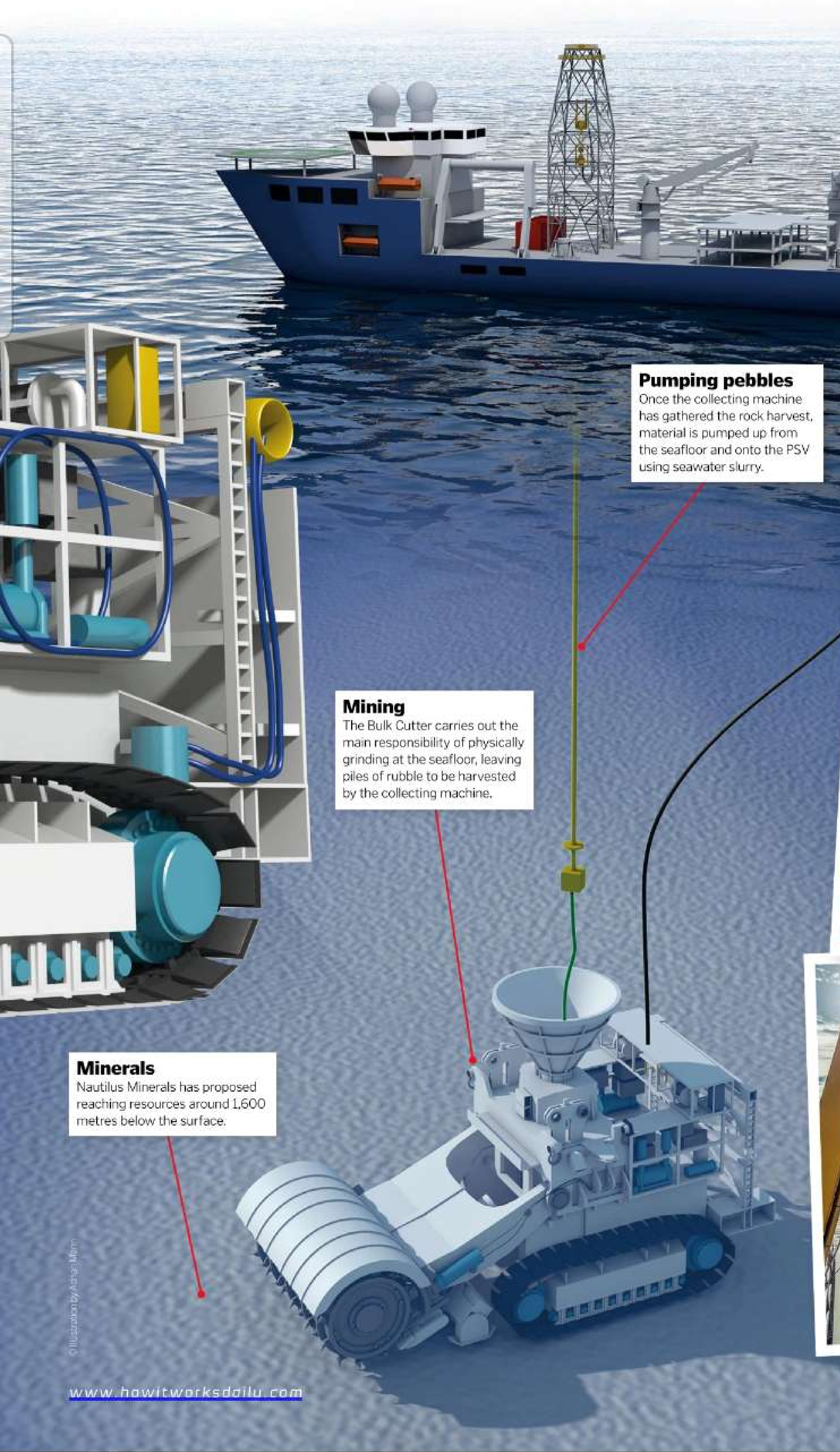
Hidden treasure

How do gold and copper deposits find themselves at the bottom of the ocean? It all starts where two tectonic plates meet and rub shoulders. At these boundaries, seawater begins to flow into cracks between this rocky union, where it is heated by convection from the Earth's molten middle. In turn, minerals from surrounding rock are dissolved into the seawater, which then erupts back onto the seafloor. As the hot water hits the cold ocean, the dissolved minerals precipitate out and settle on the seafloor. Sheets of valuable metals such as copper and gold collect, and over time form chimneys of metal sulphide-rich hydrothermal vents.

© Alamy

Trapped within the chimney of a hydrothermal vent is a gold and copper treasure

DID YOU KNOW? *The deepest known point in the Earth's ocean is 10,984 metres down, called the Challenger Deep*



Production Support Vessel (PSV)
As the base of operations for deep-sea mining, the PSV is the location of subsea machine operators and the site where mined material is stored in four holding tanks.

Pumping pebbles
Once the collecting machine has gathered the rock harvest, material is pumped up from the seafloor and onto the PSV using seawater slurry.

Mining
The Bulk Cutter carries out the main responsibility of physically grinding at the seafloor, leaving piles of rubble to be harvested by the collecting machine.

Minerals
Nautilus Minerals has proposed reaching resources around 1,600 metres below the surface.

© Illustration by Adrian Mann

An inland underwater mining machine is lowered off and onto the deck above a flooded pit by shipyards specialist Damen

©Damen Shipyards Group

Smart home security

Meet the team of digital devices working together to protect homes

Words by **Ailsa Harvey**

One of the biggest fears for most when they leave home – either for short or prolonged periods of time – is the risk of leaving their most valuable possessions. Did I definitely lock the door? What if it looks too obvious that we're all away? Should I have hidden my valuables just in case?

In the past few years, home security has been upgraded with the latest smart technology to assuage our worries. Using traditional components of security systems, smart devices allow the homeowner to monitor, control and even interact with their house from any location using the internet. When something unusual occurs, the devices will flag up the areas of concern, presenting the problem and in some cases intervening to deter any threats.

Stay at home security robots

Working as personal security guards, robots can patrol your home to observe what goes on while you are away. While each unit in a stationary alarm system can only observe from one point of view, robots can cover multiple rooms. Equipped with motion sensors, night vision and a microphone, these devices can report back to your phone with any suspicious findings.

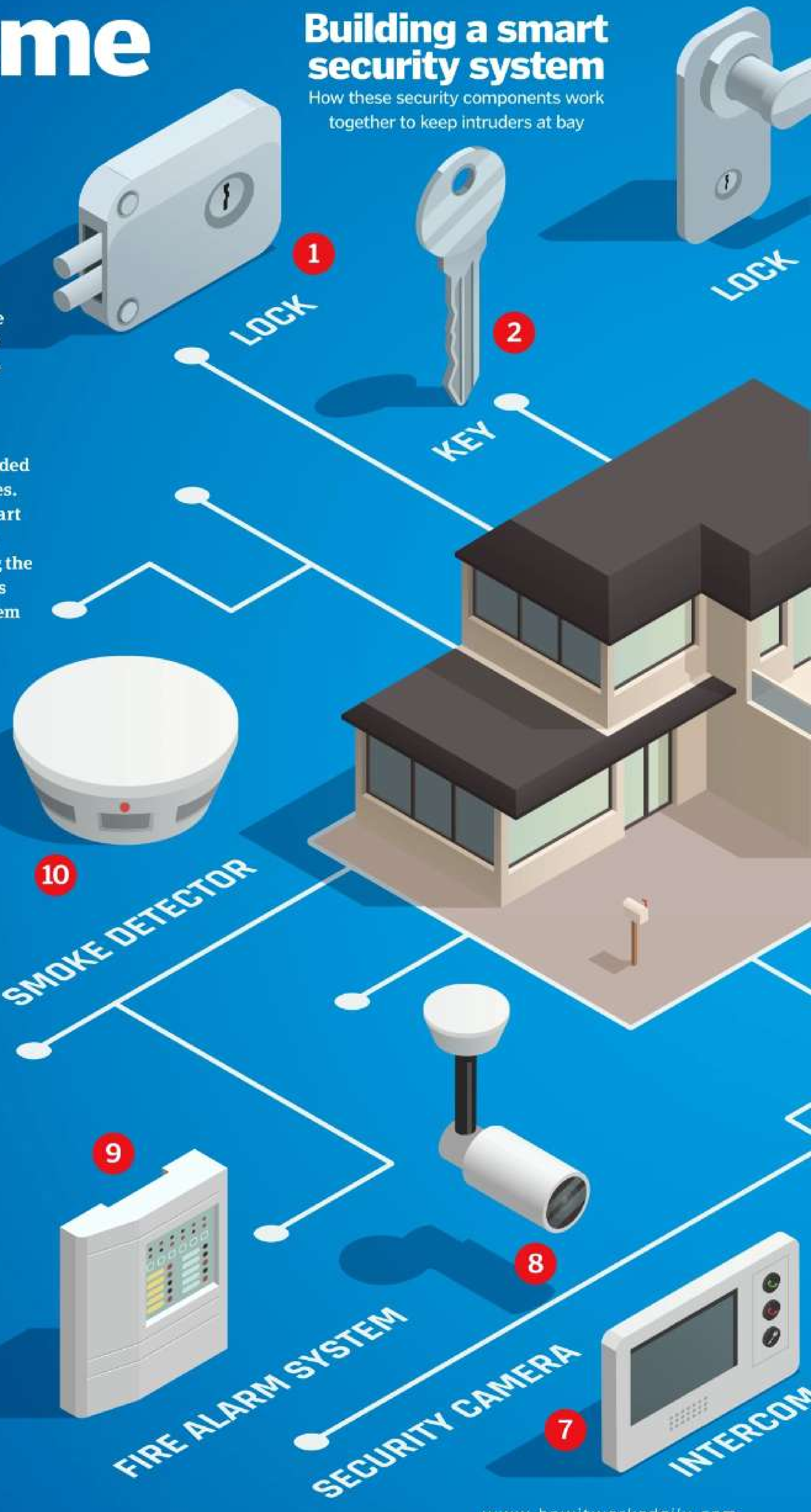
With facial recognition technology, robots can differentiate between those who are meant to be in the house and those who are intruders. Spying people it doesn't recognise instantly triggers an alert. A robot isn't likely to be able to stop a burglary, but it can take pictures of the trespasser and increase the chances of them getting caught.

© Shutterstock

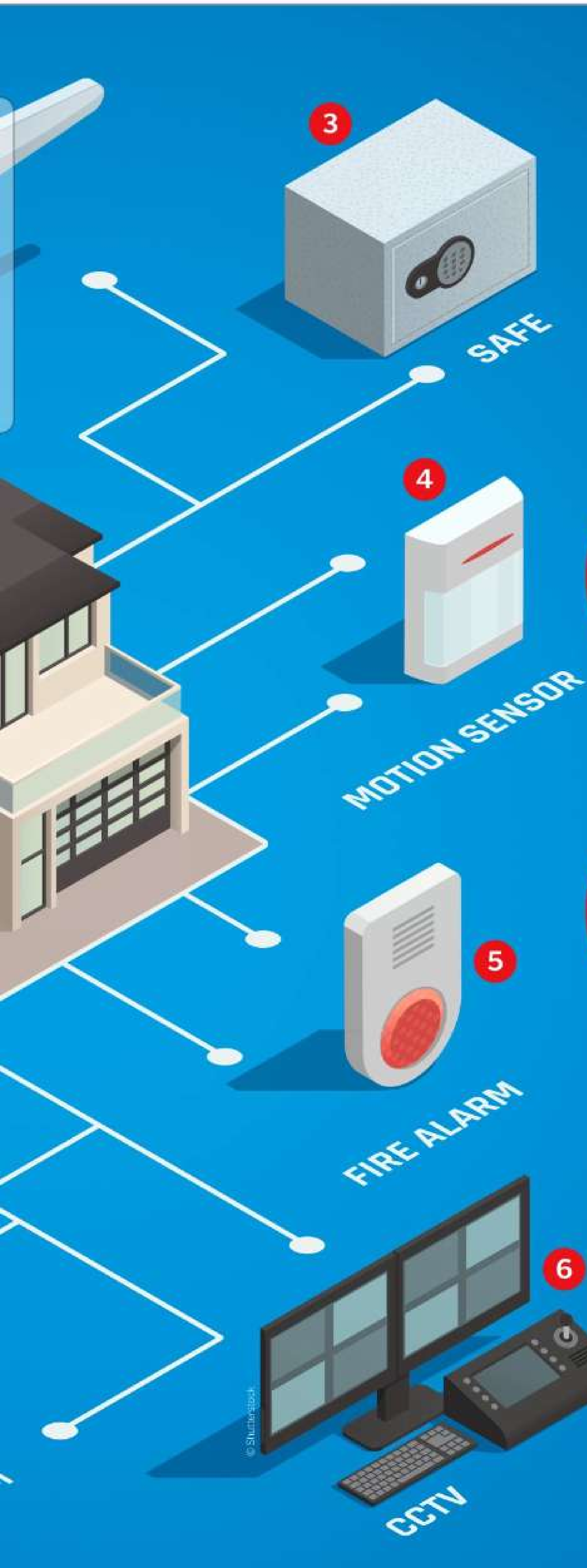
You don't have to wait for security bots to alert you. They can be controlled with a smartphone

Building a smart security system

How these security components work together to keep intruders at bay



DID YOU KNOW? *30 per cent of burglars enter homes through unlocked doors*



1 Locks

Smart locks lock your home without needing a key. Connected to a smartphone app, they let you lock and unlock the door from wherever you are. If you have ever been filled with feelings of doubt at having locked the door when you left, smart locks can bring peace of mind by allowing you to check. They can also send a notification to tell you that you've forgotten. To do this, smart locks are connected to your home WiFi, enabling it to receive the smartphone command and lock the door.

2 Key safety

If your house doesn't have a smart lock, there can be occasions when someone needs access to your house while you're not home. Hiding a key somewhere seems a bit risky, and leaving the door unlocked just isn't an option. This is where key safes can come in handy. Installed in a discreet location, key safes can hold a key outside the building safely. All you need to do is tell those you want to give access to your house the code and they can safely enter without you being there.

© Alamy

3 Safes

Keeping intruders out is one thing, but if break-ins do happen, extra security comes in the form of safes. Your most valuable items can be stored in a secure container. With internet connectivity, you can keep track of your safe's wellbeing, receiving real-time alerts if it's broken into as well as being able to control the conditions inside for your prized possessions such as the temperature.

© Getty

4 Motion sensors

Placed in various spots around the house, motion sensors can let you know when someone is in your home. With adjustable sensitivity settings, motion sensors can detect a warm body using a passive infrared sensor, and some can even recognise what movements are just your pet and what are more suspicious. Motion sensors can work in alliance with other devices such as lights and alarms.

© Getty

5 WiFi fire detectors

Intelligent smoke alarms can provide specific information into where issues lie. WiFi-connected detectors can link to your smartphone, alerting you of a fire wherever you are. The instant alert means that valuable time isn't lost, potentially saving parts of your home in a real fire emergency.

6 CCTV

While CCTV usually just records images, smart CCTV systems can recognise what they see. This may seem intrusive for those living nearby, but some smart systems have this covered with the technology required to blank out windows and gardens where people value their privacy. Faces of passers-by can also be erased, only being revealed if an incident occurs.

© Getty

7 Intercom system

Being able to see and speak to someone as they come to your front door provides a security step before opening the door to the unknown. With modern intercoms, images and audio can be sent to more than one location. While before you could only see these from inside the house, smart intercoms can let you view who is outside your door from anywhere.

8 Security cameras

Cameras are the best way to see what is going on in your home. In the past they have purely been used to look back at break-ins and catch those involved. With smart technology, however, you can tune into your home's cameras from any location on your smart devices. You can control cameras from these devices, with zooming and night-vision mode enabled to keep a close eye on the entire room the camera sits in – both day and night.

9 Fire alarm system

Wireless fire alarm systems use signals carried to the control panel by radio waves. Being more sensitive, smart fire alarm systems are less likely to pick up false alarms. Detectors are not just used to detect smoke: heat detectors use thermistors to sense rises in temperature, while carbon monoxide detectors use a range of different chemical-sensing cells.

10 Smoke detector

Have you ever burnt a slice of toast, only to be blasted with deafening alarm noises? With smart technology, sensors can tailor their responses based on the level of urgency. They may begin with a polite message of slight smoke detection before resorting to that bracing alert.

© Getty

How to make it rain

Incredibly, simply by dispersing salts into the air, rain-bearing cumulus clouds are germinated

Words by **Scott Dutfield**

The ability to control the weather might seem like something from science fiction, but since the 1940s scientists have been altering the elements in the form of cloud seeding. As the name suggests, cloud seeding is the process by which 'seeds' – in the form of simple table salt or silver iodide – are released into the atmosphere to spawn cloud growth.

By their very nature, clouds form when evaporated water molecules condense around atmospheric dust and ice, known as a nucleus. As more water droplets collect around the nucleus, larger droplets collide and begin to form clouds. This natural seeding is what scientists have been able to replicate using aeroplane-bound flares and even ground-launched rockets. However, this process cannot create clouds out of thin air; there first needs to be some water vapour or juvenile clouds in the area so that the artificial seeds can encourage clouds to form.

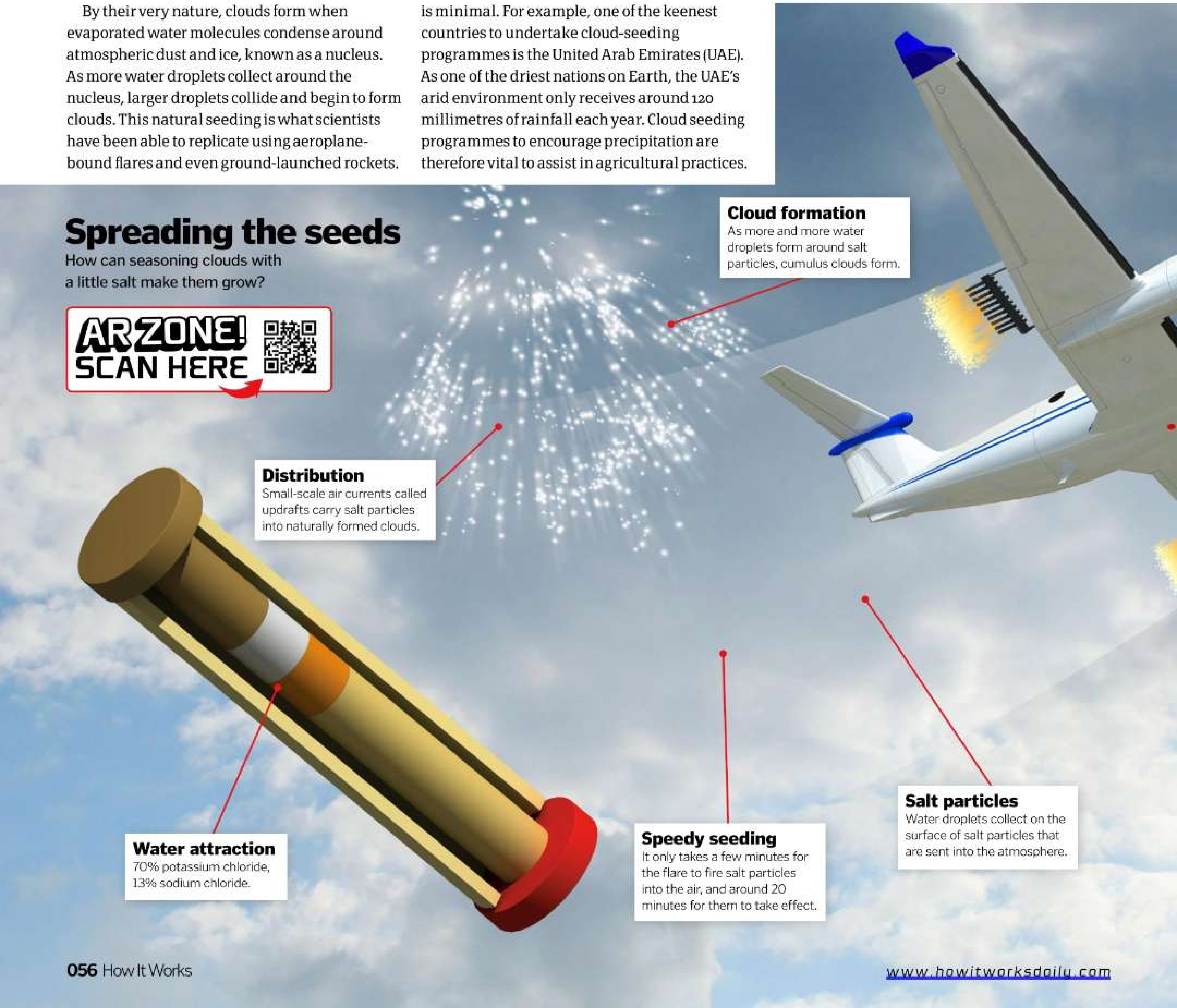
But why would we want to make clouds in the first place? Rather than simply indulging in the science of 'playing God', cloud seeding can be a lifeline to areas around the world where rainfall is minimal. For example, one of the keenest countries to undertake cloud-seeding programmes is the United Arab Emirates (UAE). As one of the driest nations on Earth, the UAE's arid environment only receives around 120 millimetres of rainfall each year. Cloud seeding programmes to encourage precipitation are therefore vital to assist in agricultural practices.

However, creating a downpour for the sake of watering plants is just one reason for cloud seeding. It is a solution for a variety of weather problems, from strategically inducing rainfall to make way for blue skies in the 2008 Beijing Olympics to preventing heavy hail storms that cause physical damage to crops.

Spreading the seeds

How can seasoning clouds with a little salt make them grow?

AR ZONE! SCAN HERE



Cloud formation
As more and more water droplets form around salt particles, cumulus clouds form.

Distribution
Small-scale air currents called updrafts carry salt particles into naturally formed clouds.

Water attraction
70% potassium chloride, 13% sodium chloride.

Speedy seeding
It only takes a few minutes for the flare to fire salt particles into the air, and around 20 minutes for them to take effect.

Salt particles
Water droplets collect on the surface of salt particles that are sent into the atmosphere.

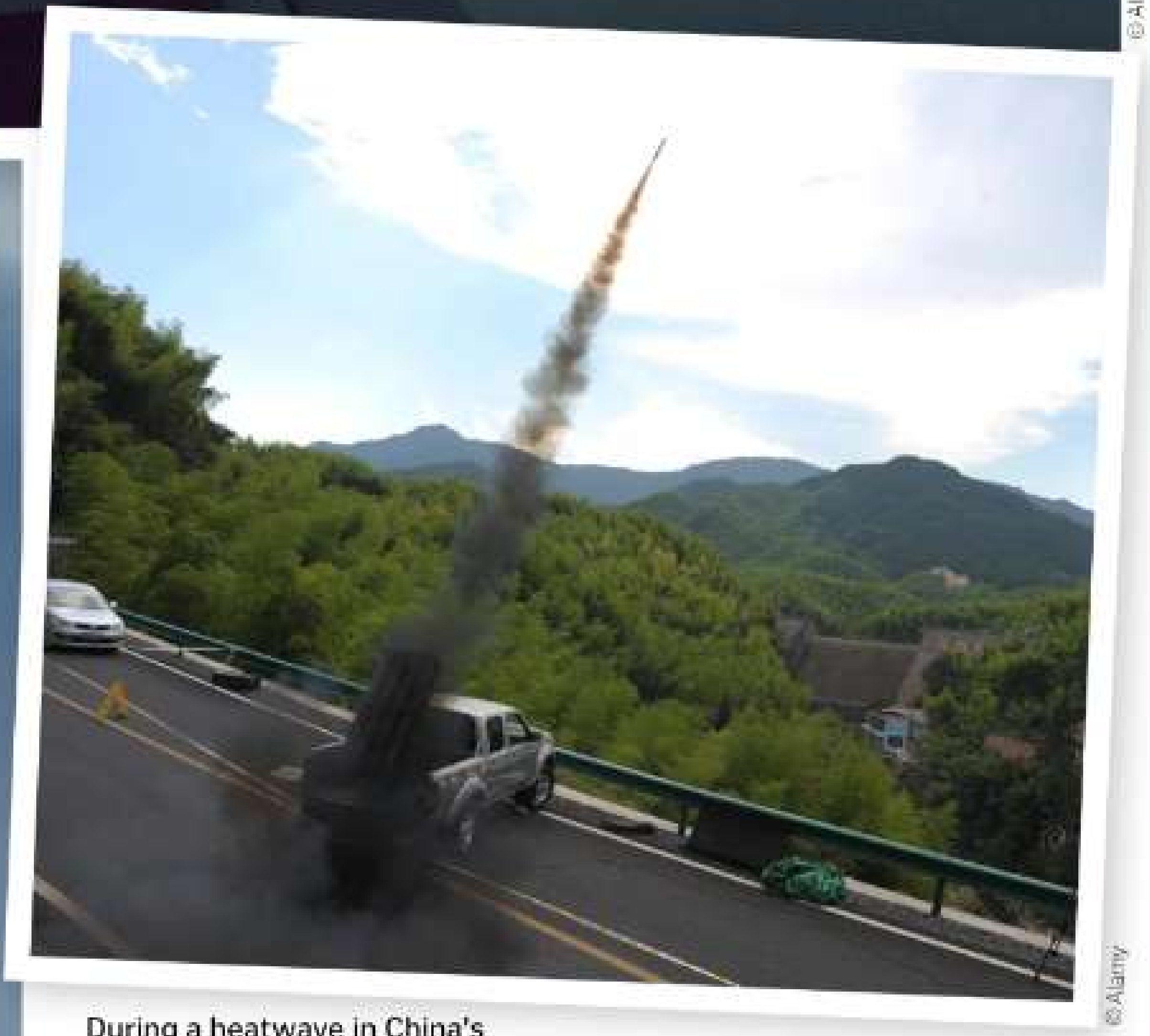
DID YOU KNOW? *In 2017 the United Arab Emirates performed 242 cloud-seeding missions*

Flares on the wings of planes distribute the salt

© Alamy

Flares
Rows of salt-containing flares are held on the wings of an aircraft.

© Illustration by Adrian Mann


During a heatwave in China's Zhejiang province, cloud-seeding rockets were used to encourage rainfall

© Alamy

A lucky discovery

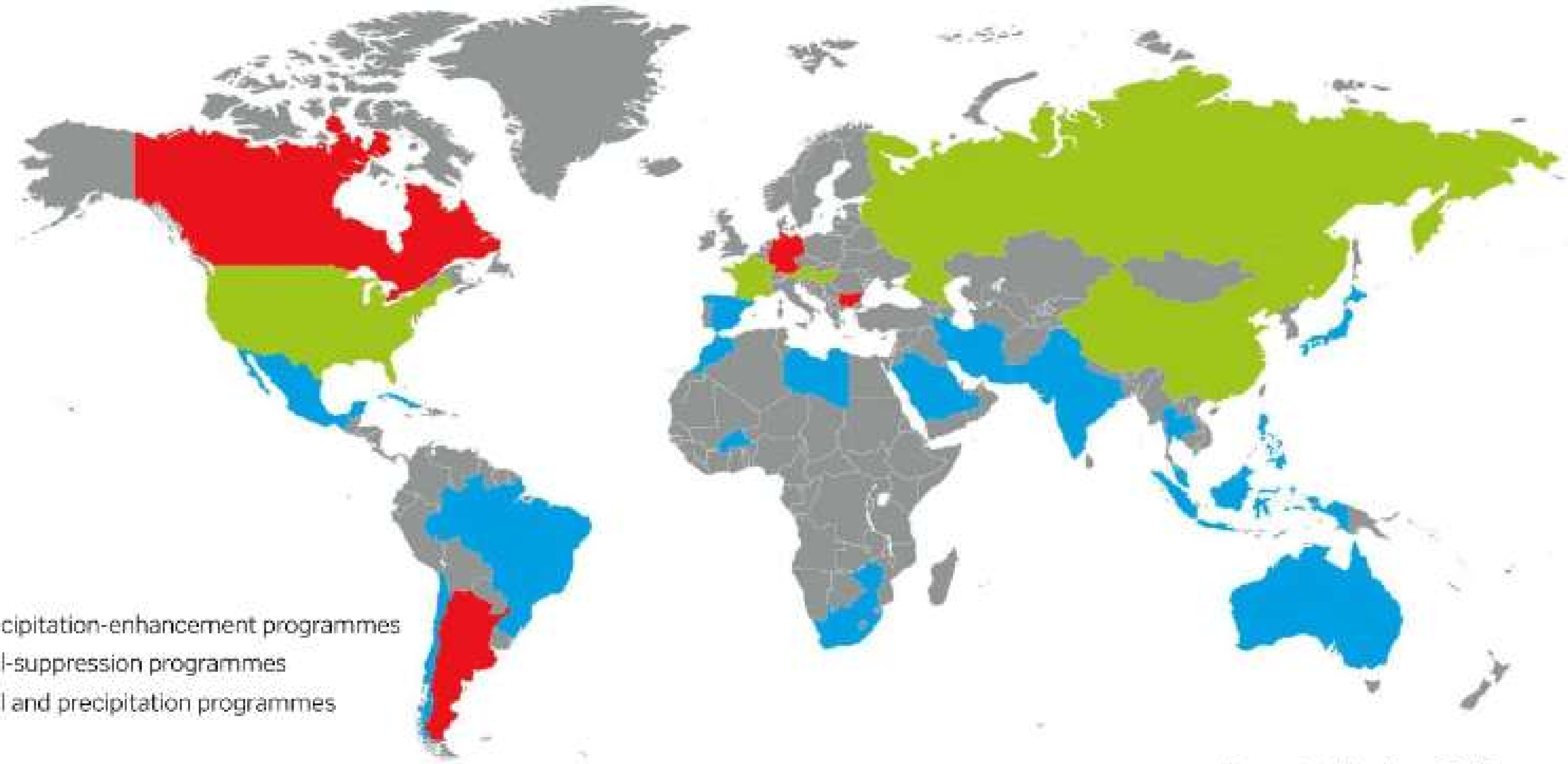
Human-made clouds were first conceived in 1946 when self-taught chemist Vincent J Schaefer began experimenting with dry ice in his laboratory fridge at the General Electric company. As with many discoveries in science, cloud seeding was uncovered serendipitously. Initially attempting to decrease the temperature of his laboratory refrigerator, Schaefer placed a piece of dry ice inside and observed millions of microscopic ice crystals form within the cold box. With the addition of his warm, moist breath, breathing into the cold box created supercooled clouds, similar to those we see in nature. Schaefer next took his experiment to the skies, releasing dry ice from an aircraft over a mountain range in Michigan, and just as he thought, human-made clouds of snow and ice grew above the mountains.

Chemist and rain-god Vincent Schaefer began working at General Electric at the age of 15

© Getty

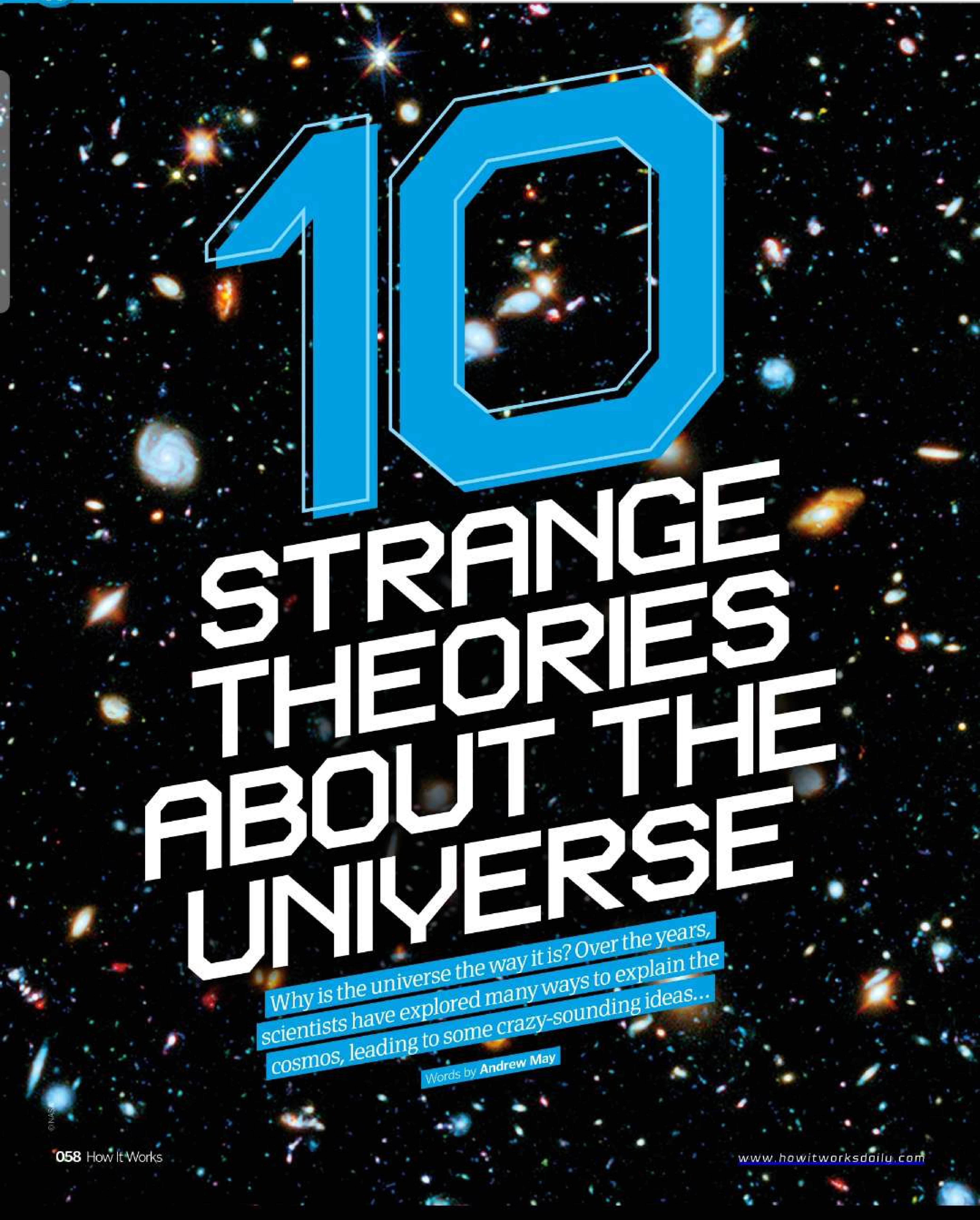
Cloud-seeding programmes around the world

Artificially creating clouds isn't just an activity that the UAE dabbles in – at least 56 countries do according to the World Meteorological Organization



KEY

- 🟦 Precipitation-enhancement programmes
- 🟥 Hail-suppression programmes
- 🟩 Hail and precipitation programmes



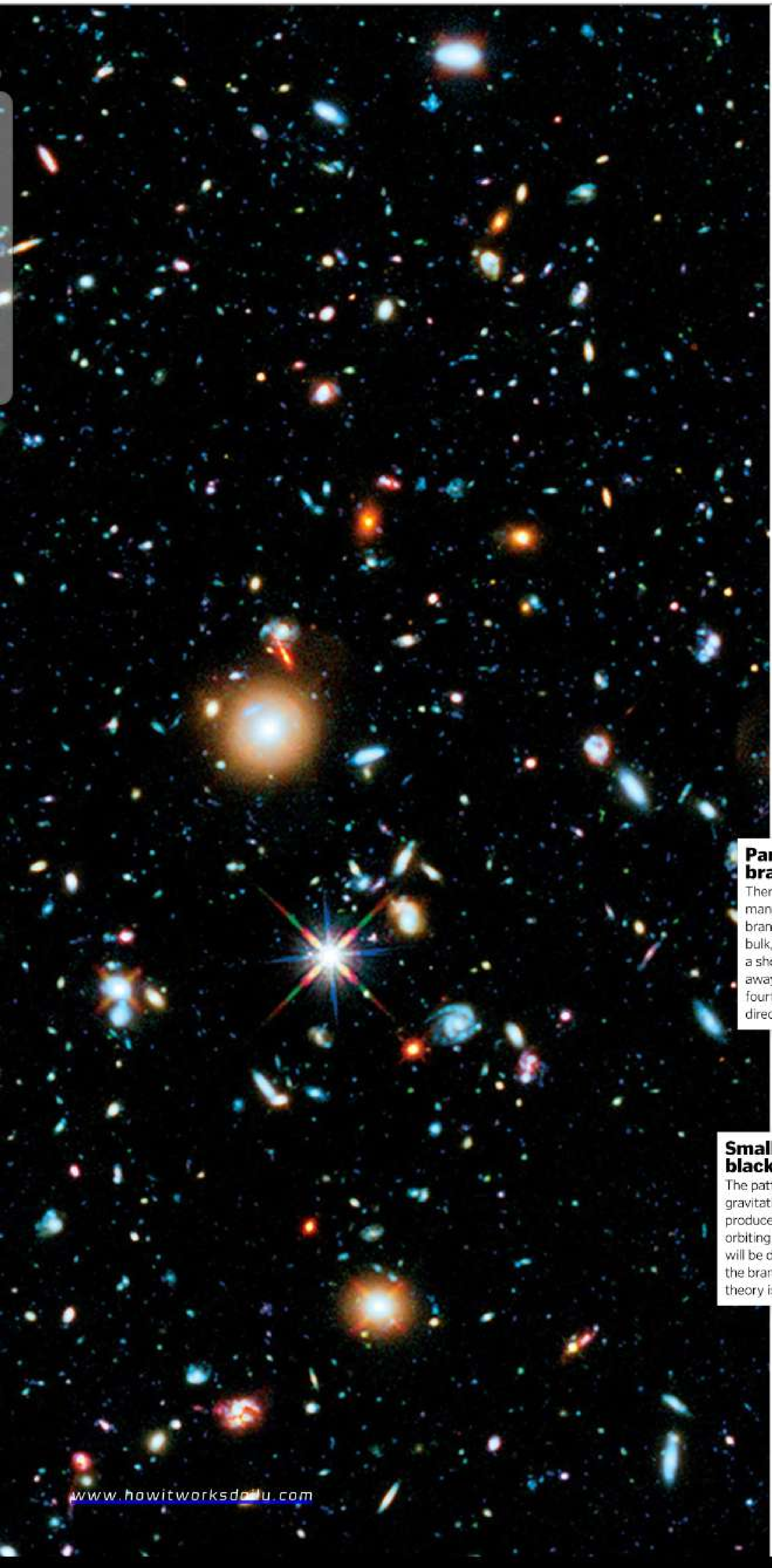
© NASA

10

STRANGE THEORIES ABOUT THE UNIVERSE

Why is the universe the way it is? Over the years, scientists have explored many ways to explain the cosmos, leading to some crazy-sounding ideas…

Words by **Andrew May**



1

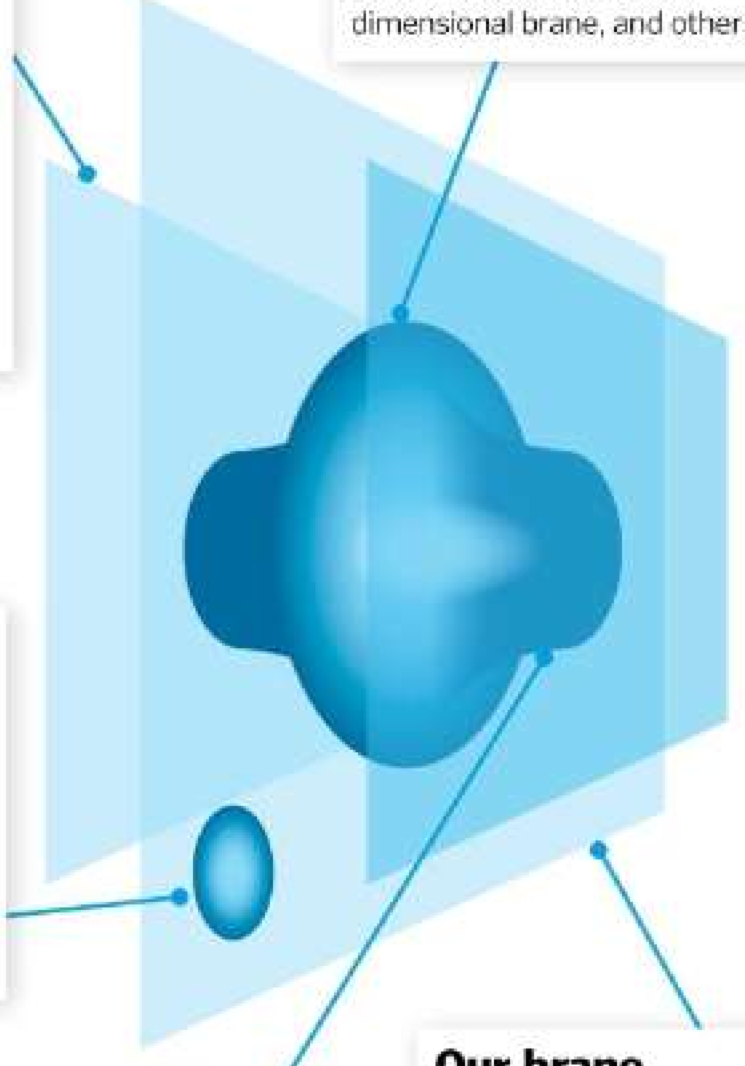
Braneworld

An aspect of the universe we take for granted is that it's three dimensional – there are three perpendicular directions you can move in. Some theories, however, suggest another spatial dimension – which we can't perceive directly – in another perpendicular direction. This higher dimensional space is referred to as 'the bulk', while our universe is a three-dimensional membrane – or 'brane' – floating inside the bulk.

As complicated as it sounds, the braneworld picture solves several problems in physics. For example, a version proposed by Lisa Randall and Raman Sundrum explains an asymmetry in subatomic forces by suggesting the existence of other branes parallel to our own. But it's not enough for a theory to explain facts we already know – it has to make new predictions that can be tested experimentally. In the case of the Randall-Sundrum model, such tests could involve measuring gravitational waves emitted by black holes linking our brane to another.

Insane in the brane

Crazy theory or the truth of the cosmos?



The bulk
It's difficult to show in a two-dimensional image, but this is a four-dimensional space containing our own three-dimensional brane, and others.

Parallel brane
There may be many other branes in the bulk, some only a short distance away in the fourth spatial direction.

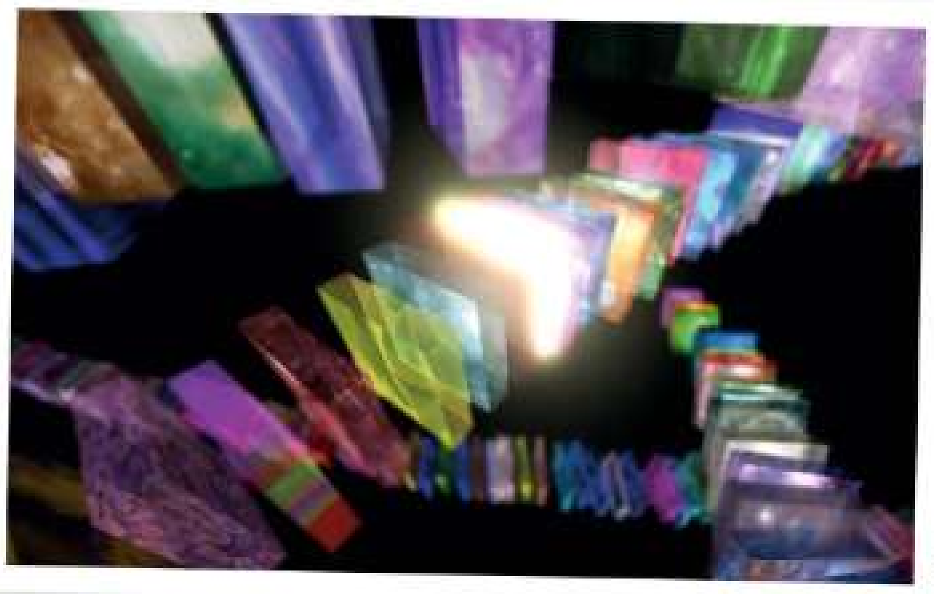
Smaller black hole
The pattern of gravitational waves produced by the orbiting black hole will be different if the braneworld theory is correct.

Black string
A large black hole might actually be a 'black string' spanning the gap between our brane and a nearby one.

Our brane
Our three-dimensional universe is embedded in the bulk, analogous to a two-dimensional membrane in a three-dimensional space.

2

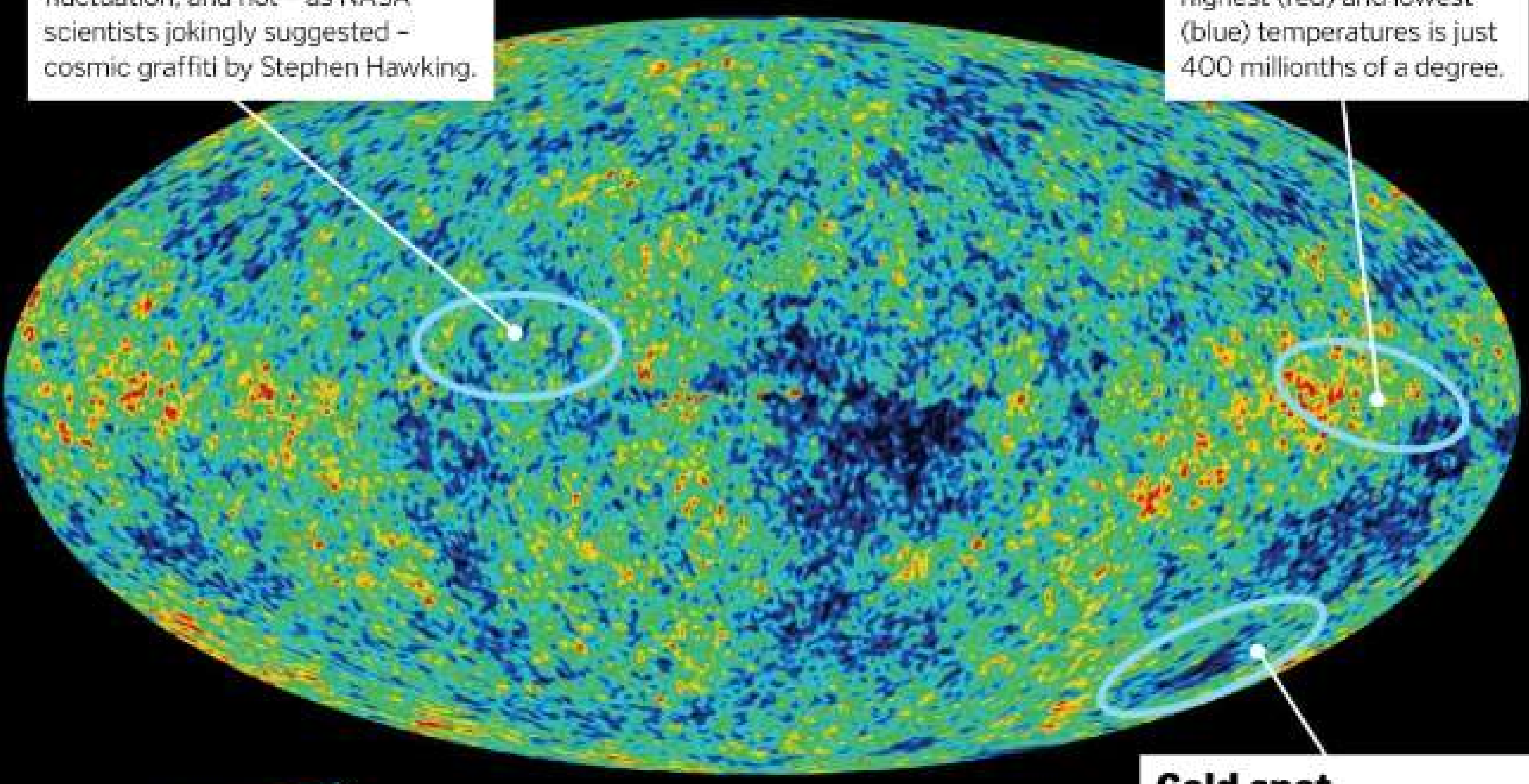
The Big Splat



© NASA

Artist's impression of multiple 'braneworlds'. When two collide, they may create a new universe

In the far future, galaxies will eventually drift so far apart that light from one can never reach another. In fact, as stars get old and die, there will come a time when there's no light – or heat – left. The universe will be a dark, cold, empty void. It sounds like the end of everything, but according to one theory, it's actually the beginning of the next universe in an endlessly repeating cycle. Remember the braneworld theory? What happens when one cold, empty brane collides with another – which, given enough time, it's bound to do eventually. Cosmologists Neil Turok and Paul Steinhardt believe such a collision would generate enough energy to create a whole new universe. They call this the 'ekpyrotic theory', though physicist Michio Kaku has more evocatively dubbed it the 'Big Splat'.



Initials 'SH'
Almost certainly another random fluctuation, and not – as NASA scientists jokingly suggested – cosmic graffiti by Stephen Hawking.

Tiny fluctuations
The difference between the highest (red) and lowest (blue) temperatures is just 400 millionths of a degree.

Cold spot
This could be the imprint of a collision with another universe – but it's probably just a random statistical fluctuation.

3

Plasma-filled cosmos

The Big Bang remains the preferred theory of many scientists, supported by two key observations – the expansion of the universe and the cosmic microwave background (CMB). Immediately after the Big Bang the universe was much smaller and hotter, filled with a glowing plasma like the Sun. We still see the end of this super-hot phase in the form of a sea of radiation filling the whole of space. The expansion of the universe over the intervening billions of years has cooled the radiation down to minus 270 Celsius, but it's still detectable by radio telescopes.

The CMB looks virtually the same in every direction, which can't be explained if the universe has always expanded at its current rate. Many scientists believe it went through a brief period of extremely rapid 'inflation' a fraction of a second after the Big Bang, suddenly ballooning in size from a subatomic scale to several light years.

The holographic universe

4

Think of a security hologram. This is basically a two-dimensional object encoding a full three-dimensional image. According to this theory, the whole three-dimensional universe may be 'encoded' on its two-dimensional boundary. It may not sound as exciting as living inside a simulation, but it has the advantage that it's a scientifically testable theory – research in 2017 showed it was consistent with the observed pattern of CMB fluctuations.

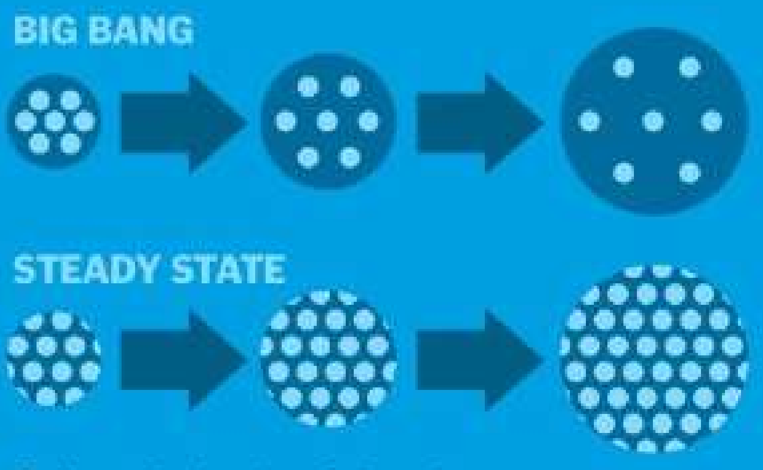
© Getty

The universe, like this hologram, may have just two dimensions despite appearing to have three

The steady-state universe

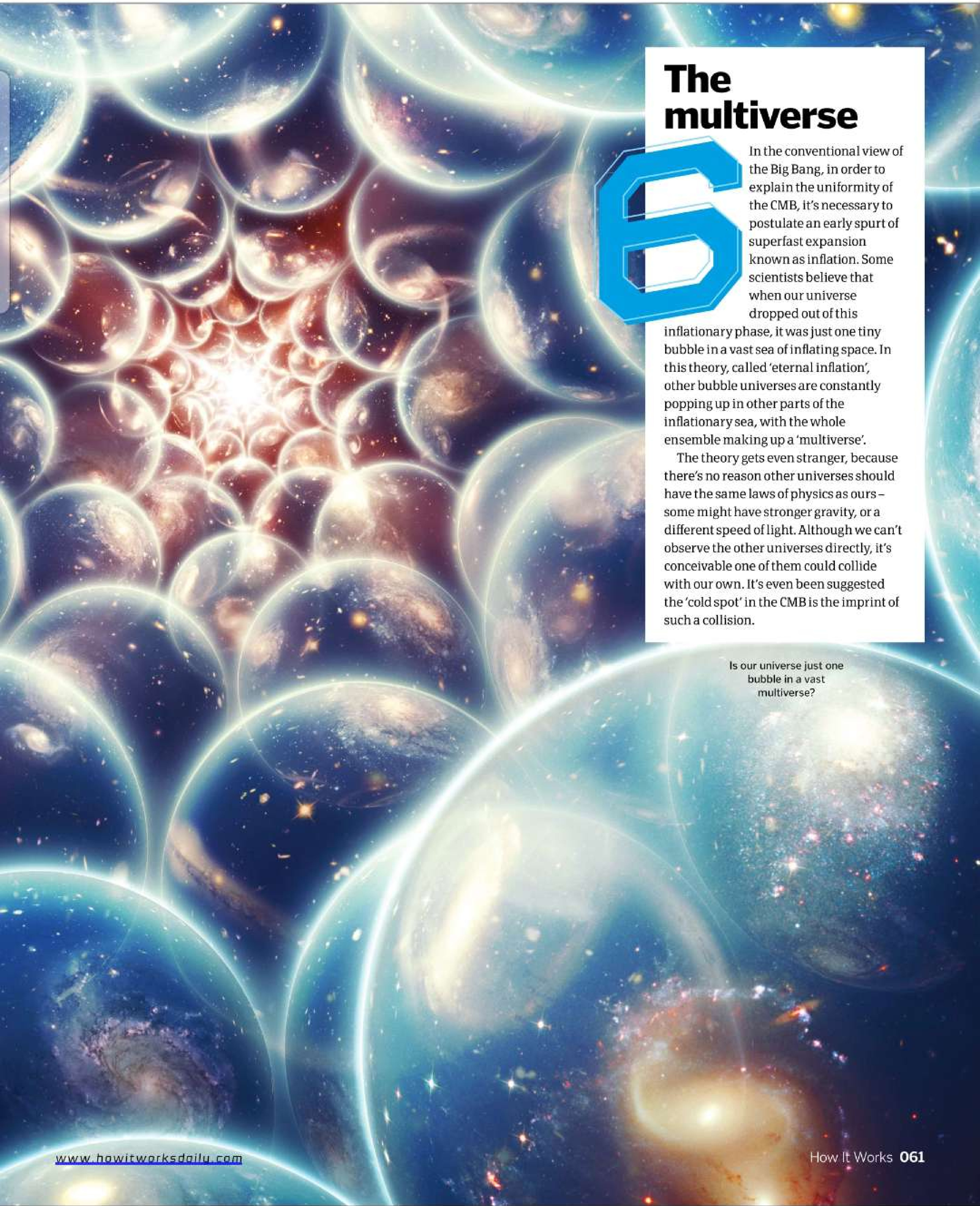
5

The Big Bang is an evolutionary theory in which the universe changes in appearance as it expands. It was denser in the past, and it will become less dense in the future. Not all scientists were happy with that, so they came up with a way for the density to remain constant, even in an expanding universe. It involves the continuous creation of matter at the rate of about three hydrogen atoms per cubic metre per million years. This model fell out of favour with the discovery of the CMB, which it can't easily explain.



To keep the density of the universe constant, new matter must be created continuously

DID YOU KNOW? *The Big Bang theory was originally formulated by a Catholic priest, Georges Lemaître*



The multiverse

6

In the conventional view of the Big Bang, in order to explain the uniformity of the CMB, it's necessary to postulate an early spurt of superfast expansion known as inflation. Some scientists believe that when our universe dropped out of this inflationary phase, it was just one tiny bubble in a vast sea of inflating space. In this theory, called 'eternal inflation', other bubble universes are constantly popping up in other parts of the inflationary sea, with the whole ensemble making up a 'multiverse'.

The theory gets even stranger, because there's no reason other universes should have the same laws of physics as ours – some might have stronger gravity, or a different speed of light. Although we can't observe the other universes directly, it's conceivable one of them could collide with our own. It's even been suggested the 'cold spot' in the CMB is the imprint of such a collision.

Is our universe just one bubble in a vast multiverse?

7 We got gravity wrong

Theories of the universe depend on an accurate understanding of gravity – the only force in physics that affects matter on very large scales. But gravity alone can't explain certain astronomical observations. If we measure the speed of stars on the outskirts of a galaxy, they're moving too fast to remain in orbit if the only thing holding them is the gravitational pull of the visible galaxy. Similarly, clusters of galaxies appear to be held together by a stronger force than can be accounted for by the gravity of visible matter.

There are two possible solutions. The standard one – favoured by most scientists – is that the universe contains unseen 'dark matter' which provides the missing gravity. The maverick alternative is that our theory of gravity is wrong, and should be replaced by something called Modified Newtonian Dynamics (MOND). The two options – MOND and dark matter – are equally consistent with observations, but are yet to be proven. More experiments are needed.

Is our galaxy surrounded by dark matter, or is the theory of gravity wrong?

© European Southern Observatory

> "Gravity can't explain certain astronomical observations"

5 FACTS ABOUT

THE BIG BANG

1 An accidental discovery The CMB was a key prediction of the Big Bang theory, so many people looked for it. It was eventually found in 1964 by radio astronomers looking for something else.

2 Space itself is expanding Although we say the universe is expanding, it's really the fabric of space itself. Any two galaxies that aren't tied to each other by gravity are getting further apart.

3 Faster than light Physical objects can't travel faster than light, but that doesn't apply to the stretching of space. During the universe's inflationary phase, space expanded much faster than light.

4 The start of everything Stephen Hawking believed that both space and time were created at the Big Bang. Before that, neither time nor space existed.

5 The missing link The reason why there are so many competing theories of the universe is that physicists don't know how to combine gravity and quantum physics. Until they do, it's all guesswork.

According to some philosophers, the universe is a computer-generated illusion projected into our brains

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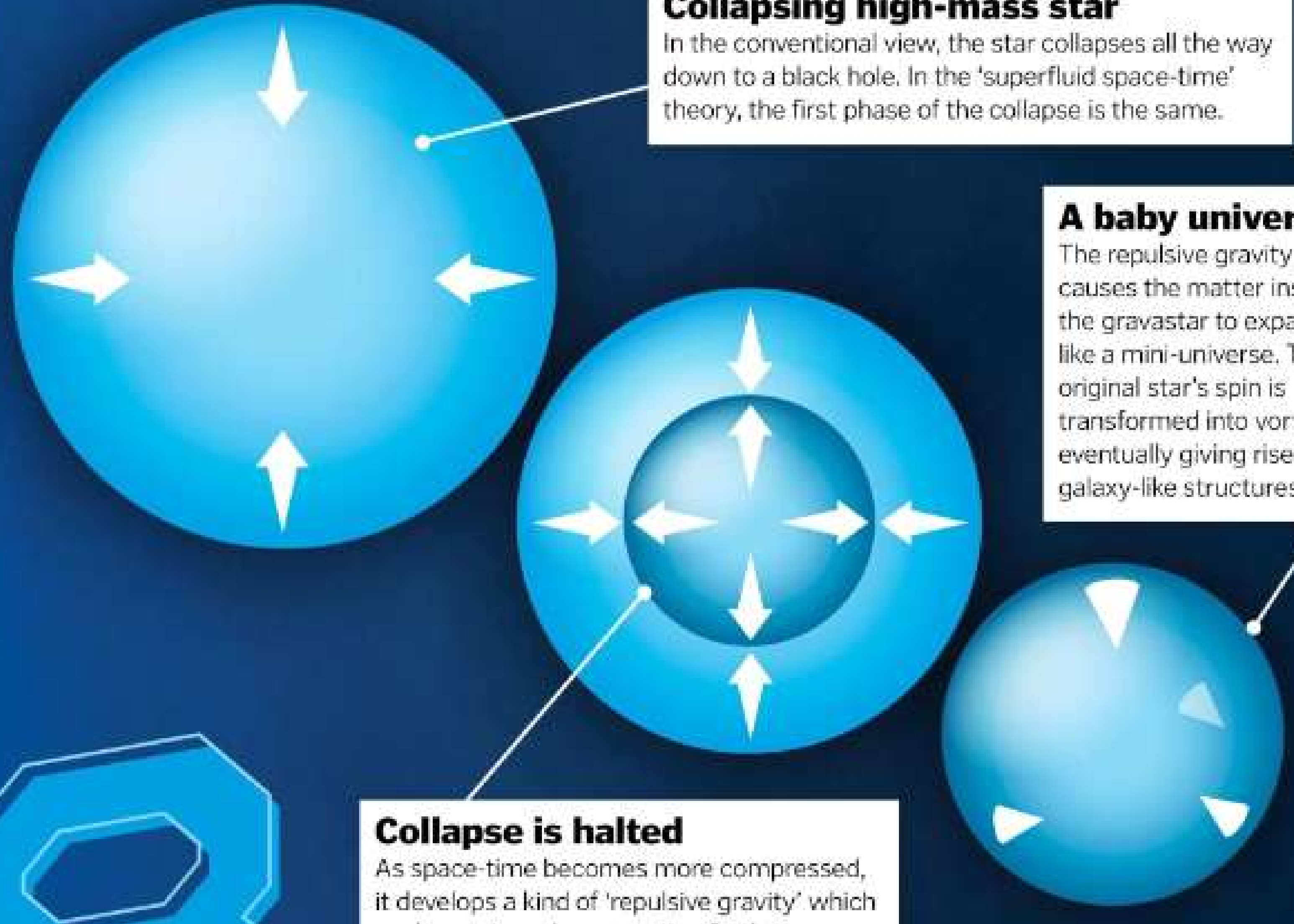


Collapsing high-mass star
In the conventional view, the star collapses all the way down to a black hole. In the 'superfluid space-time' theory, the first phase of the collapse is the same.

A baby universe
The repulsive gravity causes the matter inside the gravastar to expand, like a mini-universe. The original star's spin is transformed into vortices, eventually giving rise to galaxy-like structures.

Collapse is halted
As space-time becomes more compressed, it develops a kind of 'repulsive gravity' which pushes outwards, preventing further collapse. Rather than a black hole, the star becomes what's called a 'gravastar'.

8

Superfluid space-time

Even if space only has three dimensions, there's still a fourth dimension in the form of time, so we can visualise the universe existing in four-dimensional 'space-time'. According to some theories, this isn't just an abstract frame of reference containing physical objects like stars and galaxies, but a physical substance in itself, analogous to an ocean of water. Just as water is made up of countless molecules, so space-time – according to this theory – is made up of microscopic particles on a deeper level of reality than our instruments can reach.

The theory visualises space-time as a 'superfluid', having zero viscosity. An odd property of such fluids is that they can't be made to rotate in a wholesale fashion, like an ordinary liquid does when you stir it. They break up into tiny vortices – which in the case of superfluid space-time, may be the seeds from which galaxies form.

Simulation theory

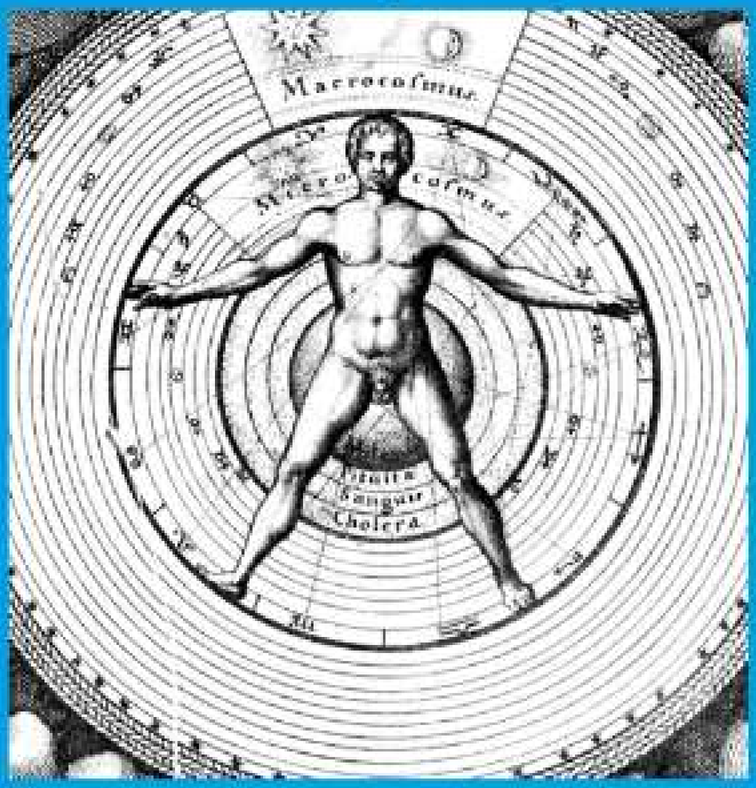
9

So far, all the theories have come from scientists – but here's one from the philosophers. If all our evidence about the universe comes into our brains via our senses and scientific instruments, who's to say it isn't all a cleverly designed illusion? The entire universe might be nothing but an ultra-sophisticated computer simulation. It's an idea that was popularised by the *Matrix* movies, but as outlandish as it sounds it's taken seriously by some philosophers. However, it fails the test of a true scientific theory, because there's no way it could be proved true or false.

Cosmic ego-trip

10

The laws of physics involve a handful of fundamental constants that determine the strength of gravity, electromagnetism and subatomic forces. As far as we know, these numbers could have any possible value – but if they departed even slightly from the values they actually have, the universe would be a very different place. Most importantly for us, 'life as we know it' – including, of course, ourselves – couldn't possibly exist. Some people see this as evidence that the universe was consciously designed in order for human-like life to evolve – the so-called self-centered 'anthropic theory'.



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The anthropic theory revives the notion that the universe was designed around human beings

What happens to the body in space?

Preventing organ damage and boiling blood, spacesuits protect astronauts from the deadly conditions of an icy vacuum

The first spacesuit worn by a human in space was in 1961

© NASA

The human body, while perfectly suited to conditions on Earth, wouldn't fare quite so well when exposed to the conditions in space. To protect it, spacewalkers wear spacesuits. These can maintain comfort for the astronaut in varying extreme temperatures, from around minus 150 degrees to plus 120 degrees Celsius. Additionally they supply oxygen to breathe, water to drink and protection from the impact of tiny particles, bright light and radiation.

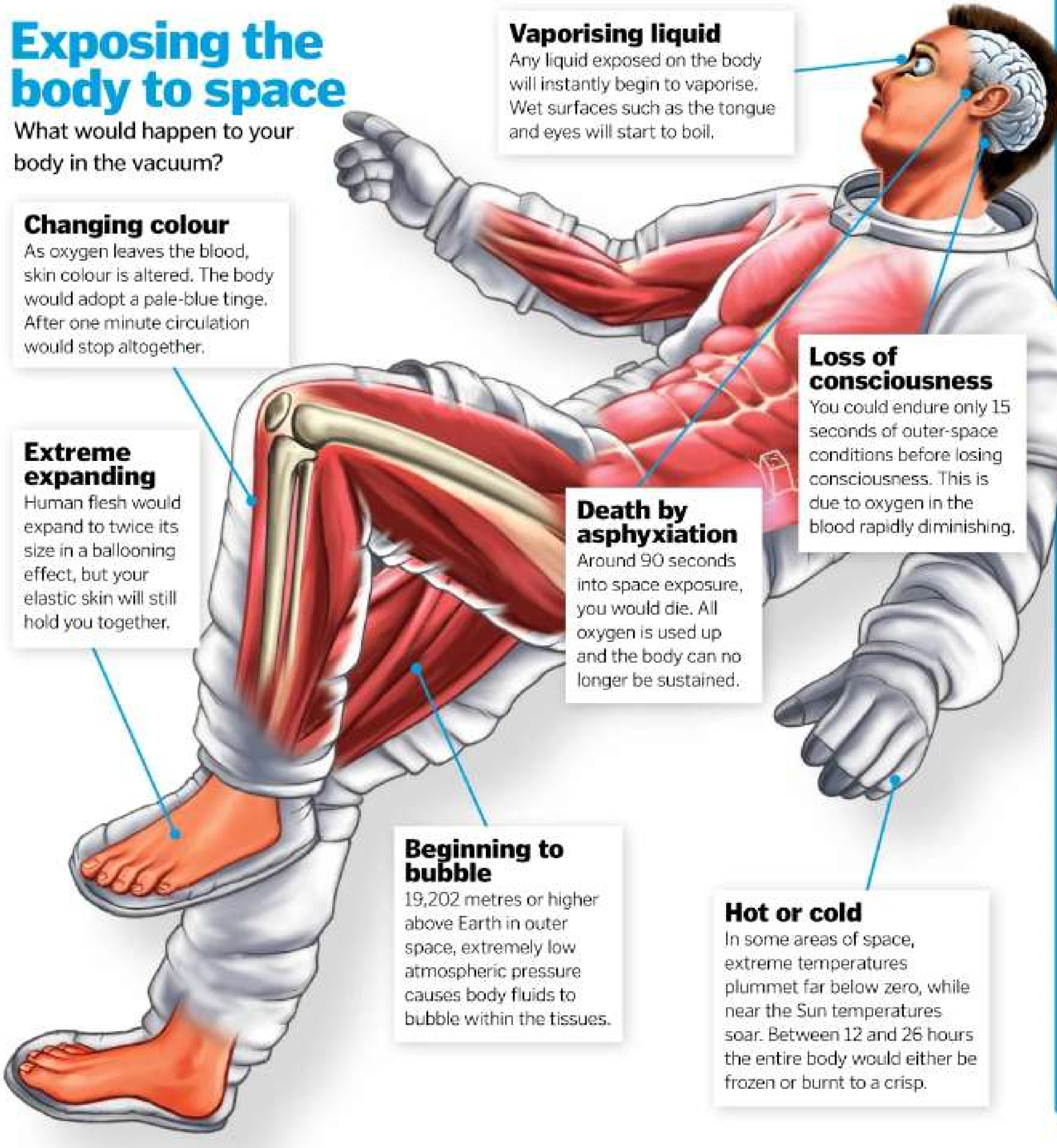
So how long could we last in space without these vital outfits? If for some reason you were to find yourself floating unprotected in space, the experience would be a brief one. You would remain conscious only for a matter of seconds before passing out and dying a few minutes later from oxygen deprivation.

Without air to breathe in the void of space, our instincts might tell us to hold our breath in this situation – but this would be a mistake. The low pressure created in the vacuum would cause any oxygen held to drastically expand, rupturing internal organs.

While spacesuits are life-saving, travelling into space can still have a huge impact on the body, even with this protection. Those enclosed in space stations are subjected to ten times the radiation experienced naturally on Earth. Astronauts who venture into orbit understand the strains they put their body under. Their specific regimes help to keep this impact on their body to a minimum, exercising daily to keep muscles strong and bone deterioration at bay.

Exposing the body to space

What would happen to your body in the vacuum?



Vaporising liquid
Any liquid exposed on the body will instantly begin to vaporise. Wet surfaces such as the tongue and eyes will start to boil.

Changing colour
As oxygen leaves the blood, skin colour is altered. The body would adopt a pale-blue tinge. After one minute circulation would stop altogether.

Extreme expanding
Human flesh would expand to twice its size in a ballooning effect, but your elastic skin will still hold you together.

Loss of consciousness
You could endure only 15 seconds of outer-space conditions before losing consciousness. This is due to oxygen in the blood rapidly diminishing.

Death by asphyxiation
Around 90 seconds into space exposure, you would die. All oxygen is used up and the body can no longer be sustained.

Beginning to bubble
19,202 metres or higher above Earth in outer space, extremely low atmospheric pressure causes body fluids to bubble within the tissues.

Hot or cold
In some areas of space, extreme temperatures plummet far below zero, while near the Sun temperatures soar. Between 12 and 26 hours the entire body would either be frozen or burnt to a crisp.

NASA's twin experiment

How can we truly compare the difference that living on a space station has on the human body to being on Earth? Much of the data we have today was collected as part of a space experiment involving identical twin astronauts. Scott and Mark Kelly took part in a detailed experiment by NASA, during which Scott spent an entire year living in space while Mark remained on Earth.

As the first experiment of its kind, the twins' identical genes enabled the study to focus purely on environmental factors. Analysing their bodies after one year, researchers found that Scott's retinas thickened due to blood swelling at the back of his eye, as well as his carotid artery in his neck. Scott lost significant weight compared to his brother and was more dehydrated overall. While these changes would return to normal shortly after landing, some wouldn't.

Scott's DNA, which had been the same as his twin's, was now slightly damaged, with chromosomes showing longer protective caps on their ends. In addition Scott suffered from a persistent reduction in cognitive ability, becoming slower and less accurate in tests.

© NASA

Scott Kelly (right) and Mark Kelly's similarities reduced the number of variables

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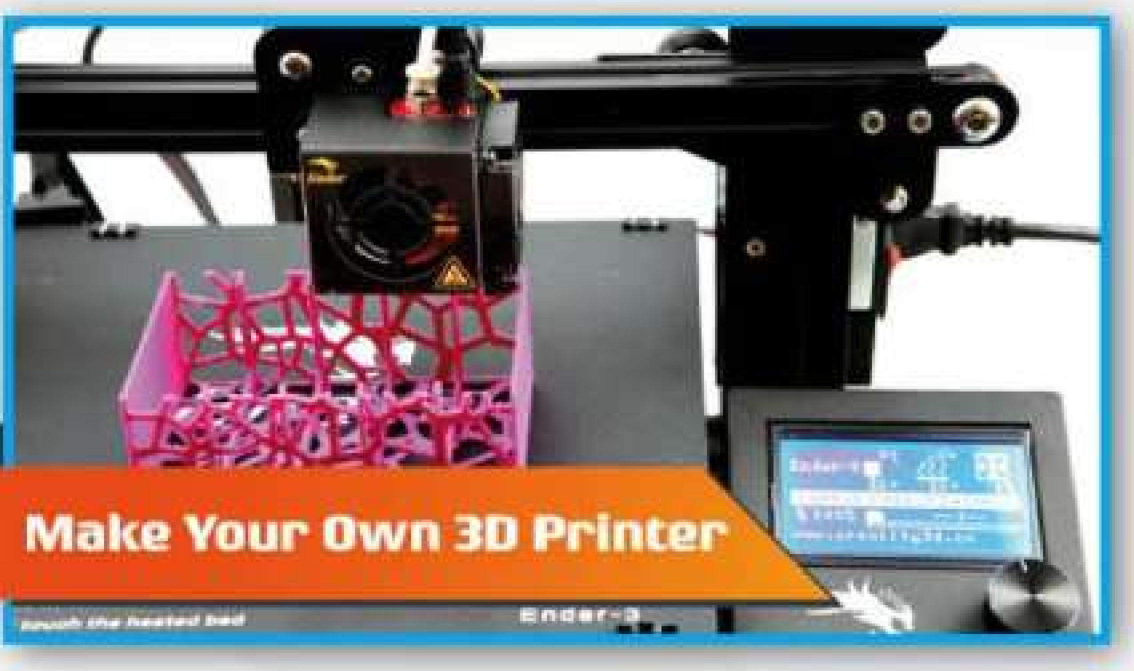
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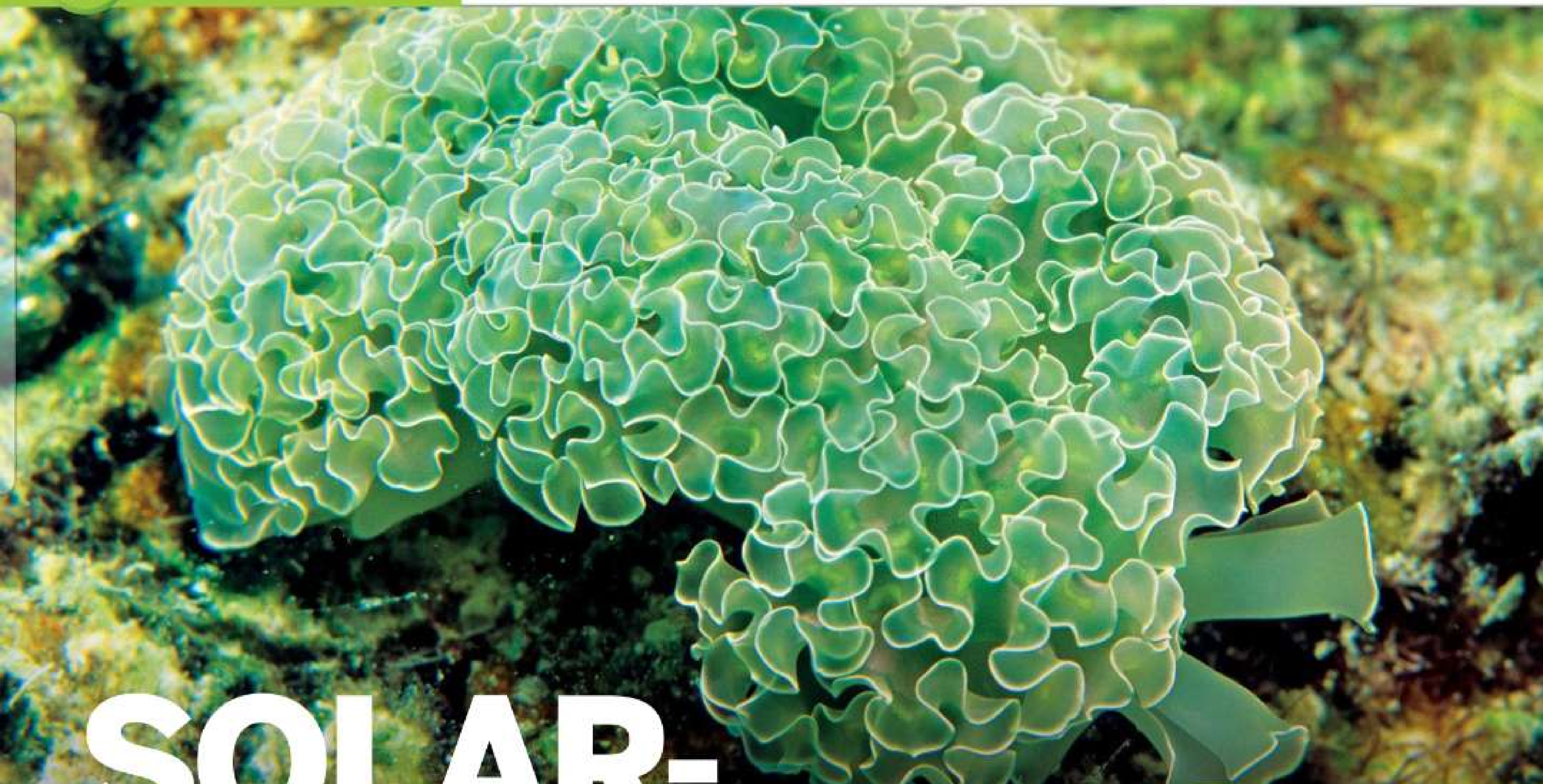
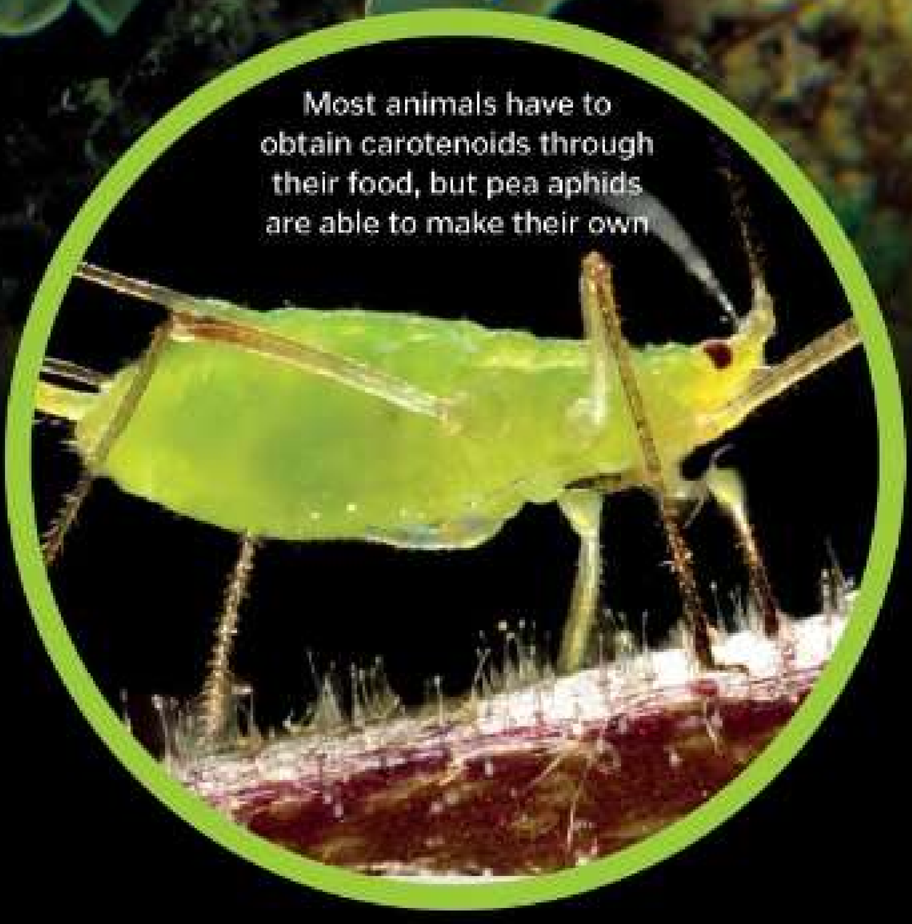


© Alamy

SOLAR-POWERED ANIMALS

Meet the creatures taking inspiration from plant photosynthesis and using sunlight to feed themselves

Words by **Scott Dutfield**



Most animals have to obtain carotenoids through their food, but pea aphids are able to make their own

© Alamy

As Earth's natural solar panels, plants obtain energy from converting sunlight into food in a process called photosynthesis. It's an ability that has ensured the survival of autotrophs – an organism that produces its own food – for around 2 billion years. But it turns out plants don't hold the monopoly on photosynthesis, as a few animal species have also been found to dabble in the art of light conversion.

Take the pea aphid (*Acyrthosiphon pisum*), for example. Typically found feasting on the stems, leaves and flowers of alfalfa plants around the world, pea aphids have evolved to mimic their leafy lunch. Rather than producing chlorophyll pigment for photosynthesis, these tiny insects can produce another pigment called carotenoids, which can also absorb sunlight and provide an energy boost for the aphids. Although this isn't a complete replacement for the aphid's plant-based diet, studies have shown green aphids produce significantly higher levels of adenosine triphosphate (ATP) – the body's energy currency – than their white counterparts, who lack the carotenoid pigments. Pea aphids are a great example of how one species can mimic another to reap the same benefits through evolution.

Just below the watery surface of salt marshes around the North American coastline, there is also a group of sun-worshipping slugs with a tendency to steal the ability to photosynthesise from their algae neighbours. Looking more like the leaf of a sycamore than a sea slug, sacoglossans are a group of marine invertebrates that feed on algae and in the process absorb their photosynthesis factories, chloroplasts. Known as kleptoplasty, sacoglossans can strip chloroplasts from their algal prey and relocate them into their own cells, where they continue to produce energy and sugars from sunlight. These sea slugs only need to feast on marine algae for the first two weeks of their life, which can sustain them for around 12 months.

One slug has taken this chloroplast kleptomania to the next level by stealing the algae's genetic information to produce its own chloroplasts. Although sacoglossan

DID YOU KNOW? *The world's plantlife produces around 176 billion tonnes of glucose through photosynthesis every year*

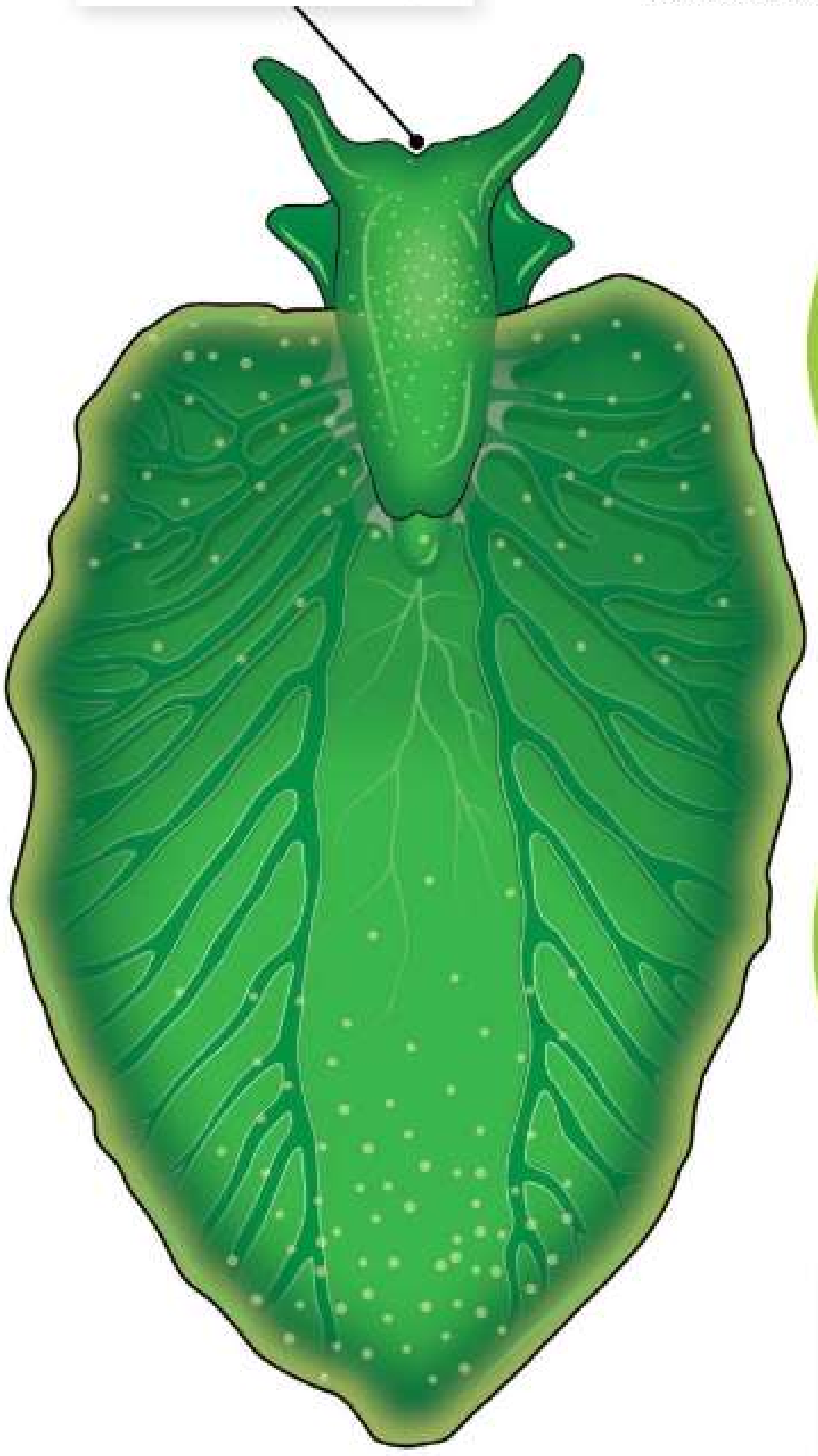
STEALING ENERGY FACTORIES

How the emerald elysia strips algae of their photosynthesis powerhouses

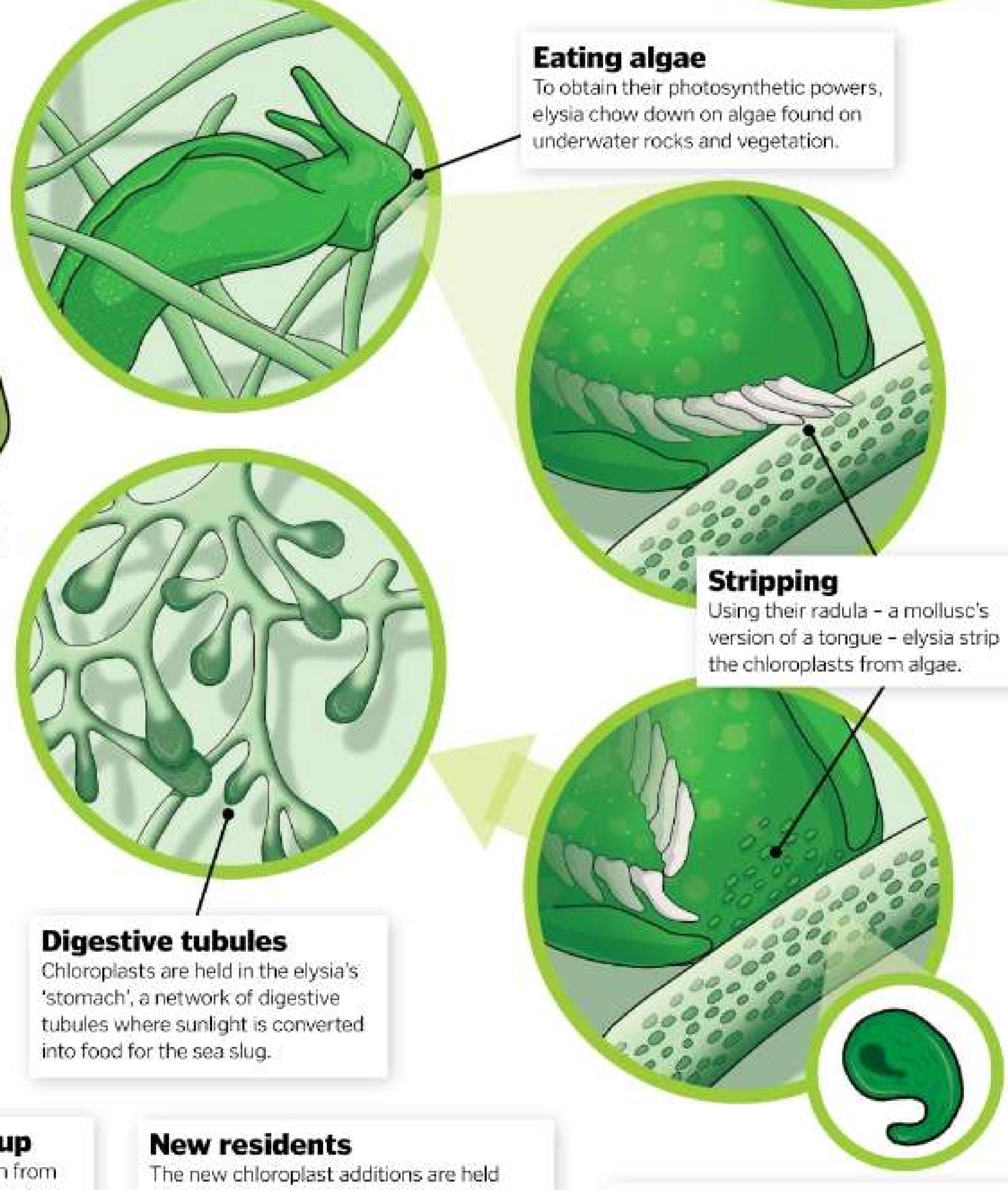
© Getty

Spotted salamanders are the only known vertebrate with photosynthetic abilities

Elysia chlorotica is a member of a genus capable of stealing algaes' method of energy production



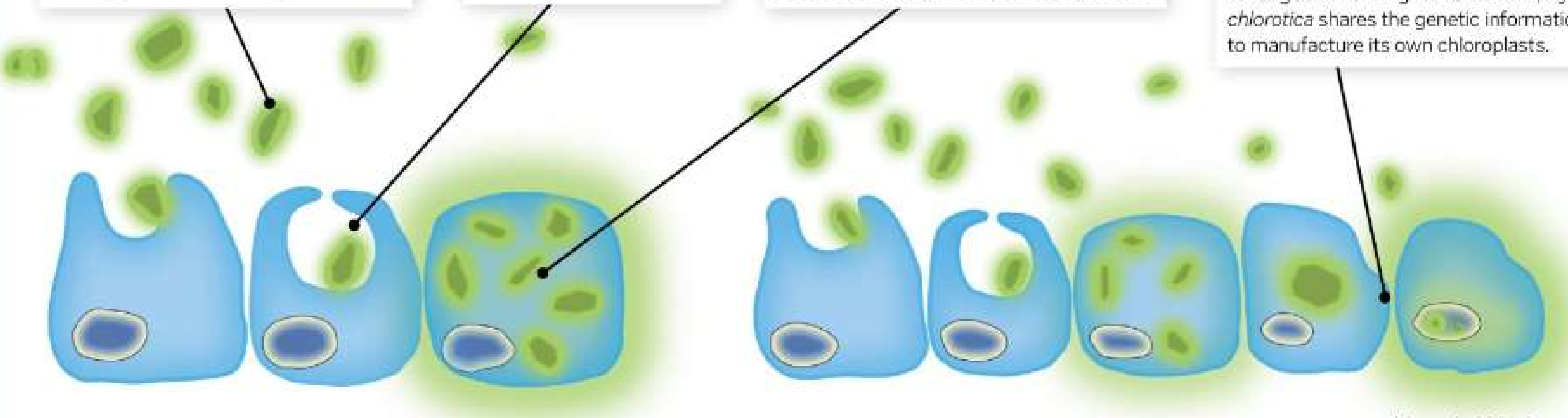
Elysia chlorotica
This leafy imposter lives in the salt marshes along the Atlantic coast and grows to be between one and six centimetres long.



Eating algae
To obtain their photosynthetic powers, elysia chow down on algae found on underwater rocks and vegetation.

Stripping
Using their radula – a mollusc's version of a tongue – elysia strip the chloroplasts from algae.

Digestive tubules
Chloroplasts are held in the elysia's 'stomach', a network of digestive tubules where sunlight is converted into food for the sea slug.



Energy conversion
Giving elysia their green colour, chloroplasts convert solar energy, carbon dioxide and water into oxygen and sugars for the sea slugs to feed on.

Suck them up
Chloroplasts taken from algae enter the membrane of the elysia's cell.

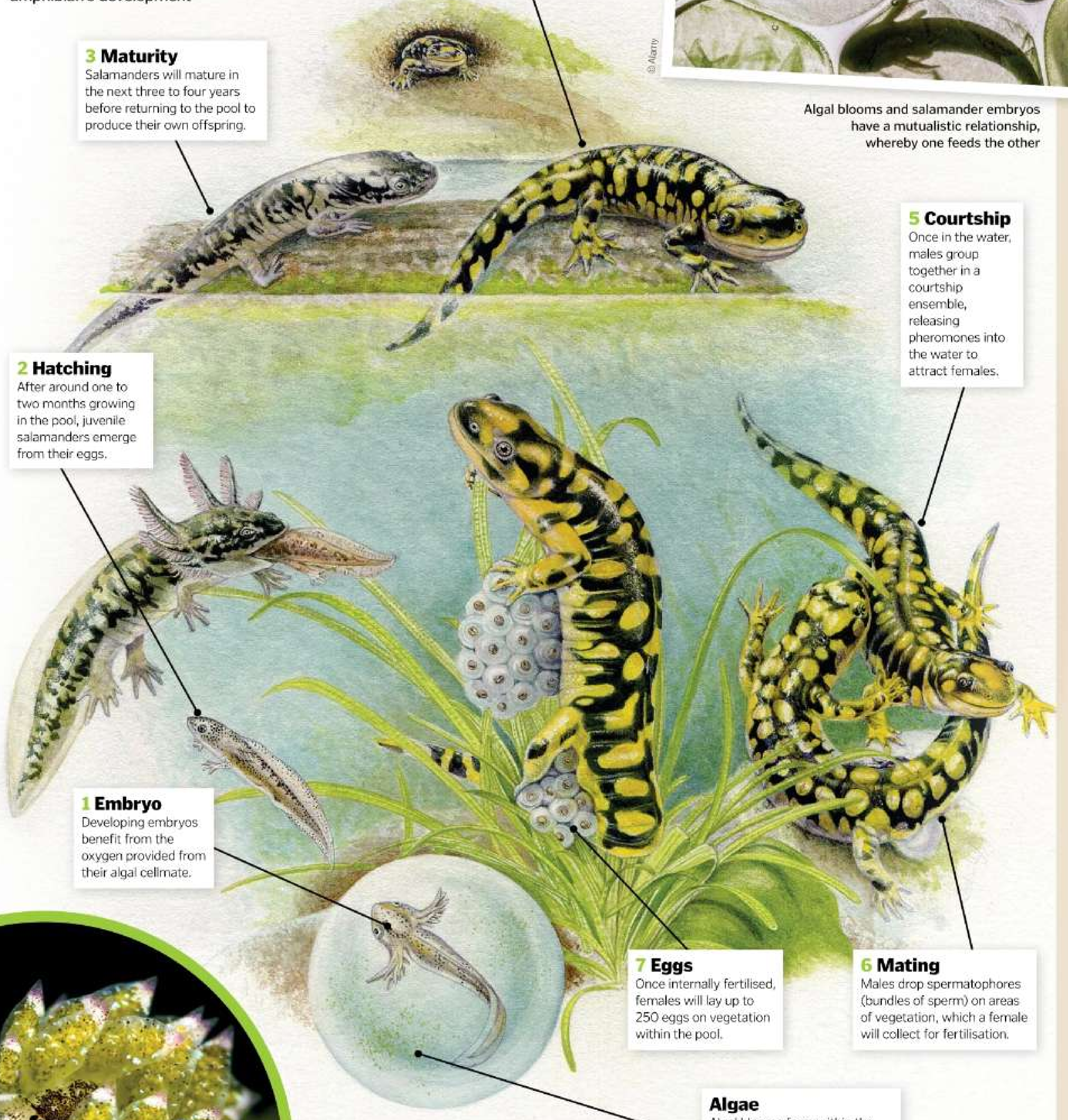
New residents
The new chloroplast additions are held within the cell, where they will continue producing energy through photosynthesis.

Genetic transfer
Through horizontal genetic transfer, *Elysia chlorotica* shares the genetic information to manufacture its own chloroplasts.

© Illustration by Ed Crooks

SPOTTED SALAMANDER LIFE CYCLE

How algae has shaped this amphibian's development



1 Embryo
Developing embryos benefit from the oxygen provided from their algal cellmate.

2 Hatching
After around one to two months growing in the pool, juvenile salamanders emerge from their eggs.

3 Maturity
Salamanders will mature in the next three to four years before returning to the pool to produce their own offspring.

4 Homeward bound
Adult spotted salamanders journey from their forest homes to the seasonal pools they originally hatched from.

5 Courtship
Once in the water, males group together in a courtship ensemble, releasing pheromones into the water to attract females.

6 Mating
Males drop spermatophores (bundles of sperm) on areas of vegetation, which a female will collect for fertilisation.

7 Eggs
Once internally fertilised, females will lay up to 250 eggs on vegetation within the pool.

Algae
Algal blooms form within the egg of a developing salamander, where they feed on excess carbon dioxide and nitrogen created by the embryo.

© Alamy

Algal blooms and salamander embryos have a mutualistic relationship, whereby one feeds the other

© Alamy

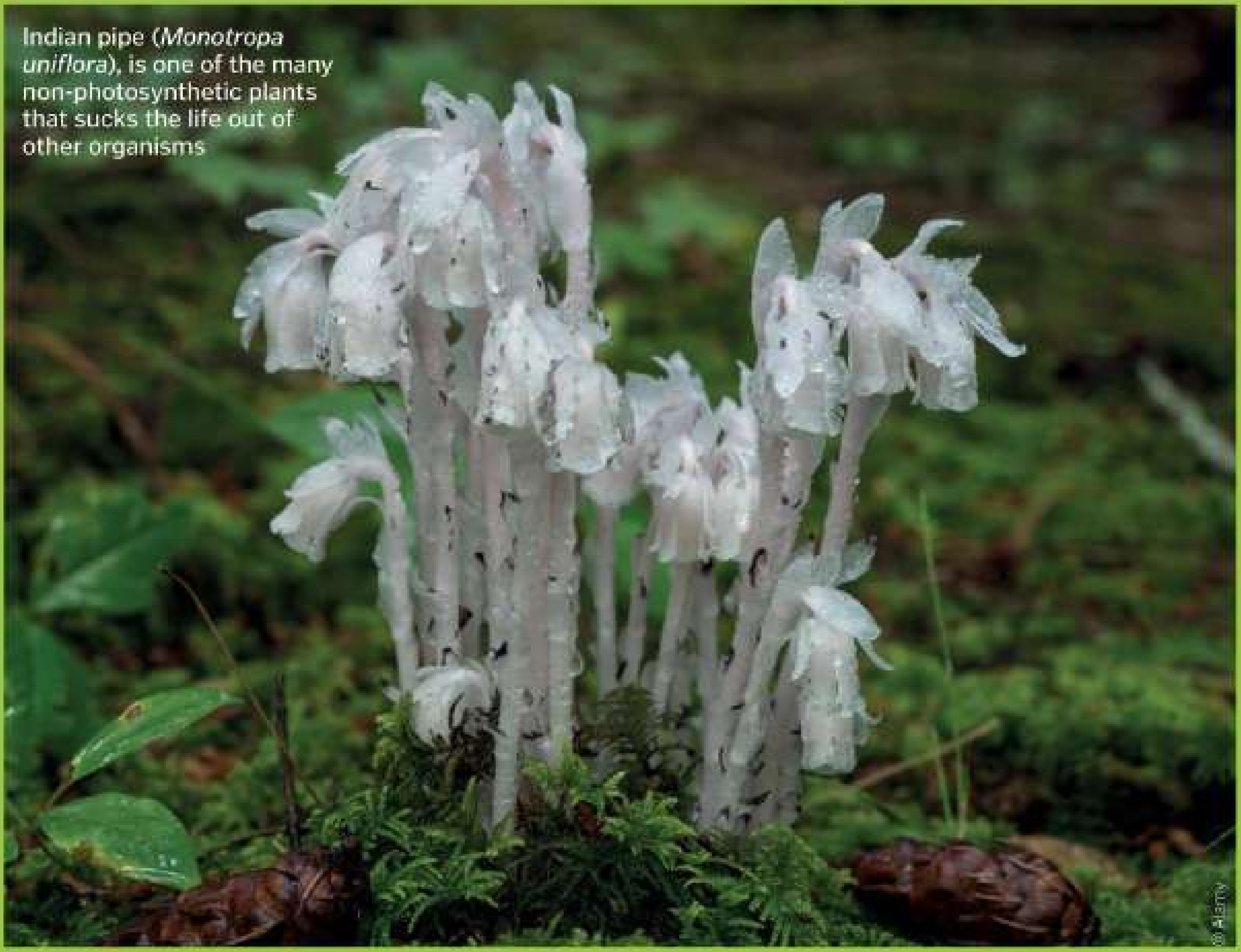
Japan's leaf sheep (*Costasiella kuroshimae*) is another sea slug capable of stealing algae's ability to photosynthesise

DID YOU KNOW? Spotted salamanders can live to be around 20 years old

slugs can survive for a whole year without eating before they run out of photosynthesis power, the emerald elysia (*Elysia chlorotica*) has evolved a way to make sure it never runs out of reserves. Initially grazing on algae and obtaining chloroplasts through kleptoplasty, the emerald elysia breaks into the nucleus of the algae and steals genetic information which codes for the production of chloroplasts in what's known as a horizontal genetic transfer. This sea slug is then able to sustain itself on the energy produced through photosynthesis, even though they still chow down on an algal lunch from time to time.

With only a few examples of animals capable of exploiting photosynthesis, especially in vertebrate species, you're not going to see green bears in the woods anytime soon. However, one vertebrate species has been discovered to harbour an algal hostage within its cells. It was previously believed that during the life cycle of the spotted salamander (*Ambystoma maculatum*), algae and a salamander embryo have a symbiotic relationship whereby both benefit from the other in the exchange of nutrients for oxygen. However, studies have shown that during development algae become incorporated into the salamander cells, where they live and provide energy to adult salamanders. It's still relatively unclear as to how exactly the algae enter the salamander's cells and why its immune system doesn't deem the algae as a threat. But what is clear is that once inside, this microscopic mutualism is no longer beneficial to both sides. Trapped in the confines of an amphibian's dark-pigmented body, access to a source of light is in short supply. Instead, these once-photosynthetic algae turn their hand to fermentation to produce food in the gut of the salamander.

> "Algae become incorporated into the salamander cells"



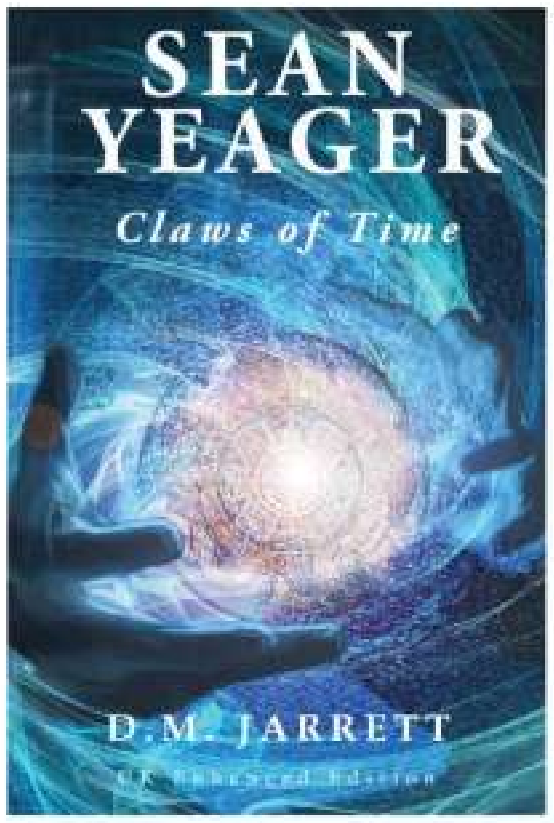
Indian pipe (*Monotropa uniflora*), is one of the many non-photosynthetic plants that sucks the life out of other organisms

© Alamy

It's not easy being green

Plants aren't always the leafy green photosynthetic organisms we think they are. Around 3,000 plant species around the world are non-photosynthetic, seeking food in other ways. One such plant is the Indian pipe (*Monotropa uniflora*). Looking more like the ghost of plants past, this colour-lacking sprout is missing any chlorophyll to convert light into energy. Instead, these North American plants obtain sugars from surrounding fungi. Known as a myco-heterotroph, Indian pipe take advantage of a group of fungi called mycorrhizae, which typically have a symbiotic relationship with other plants, trading sugars for other plant-produced nutrients. However, this ghostly species only offers a one-sided deal, stripping the fungi for its own gain.

BEWARE
THE
GREEN MAN !



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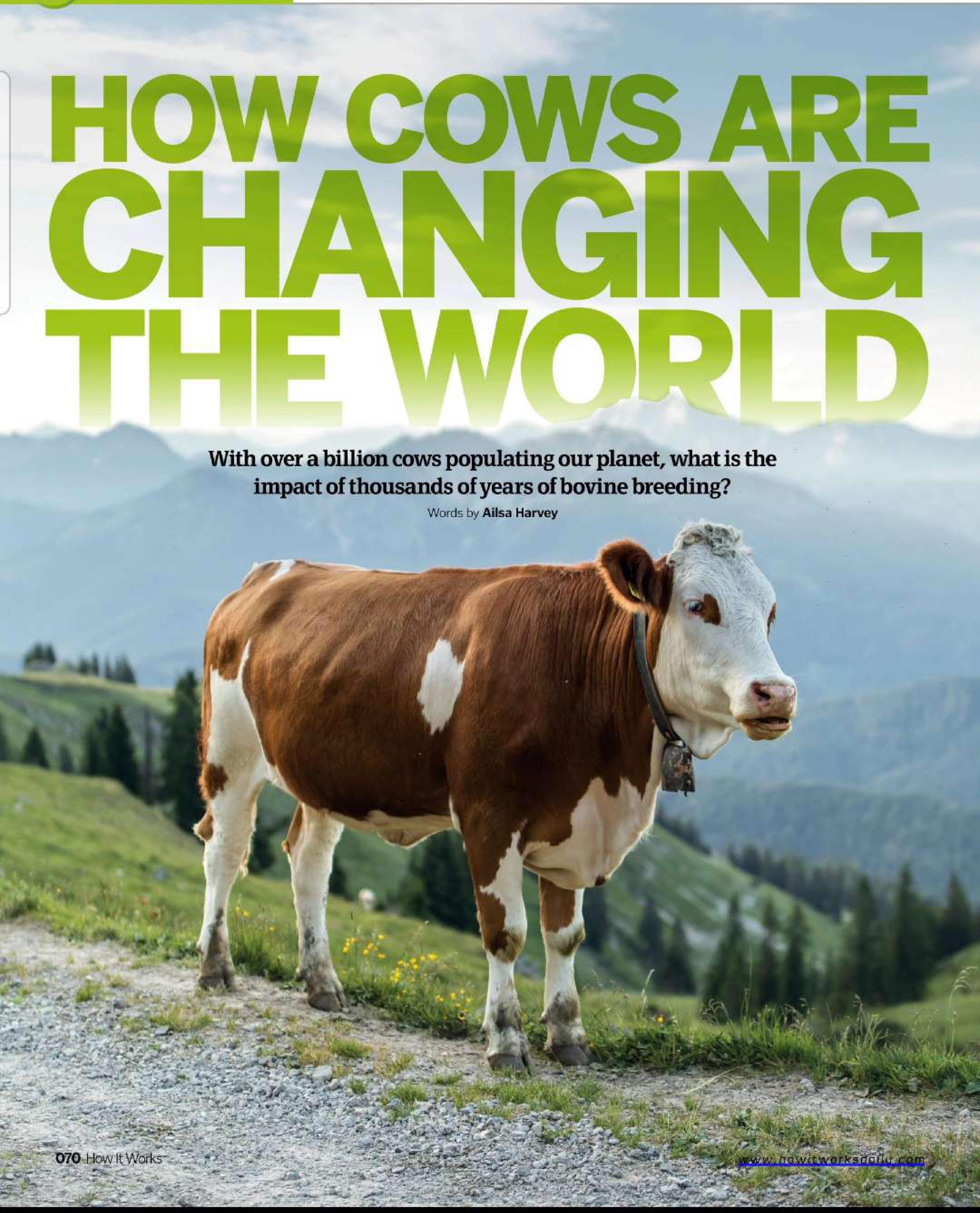
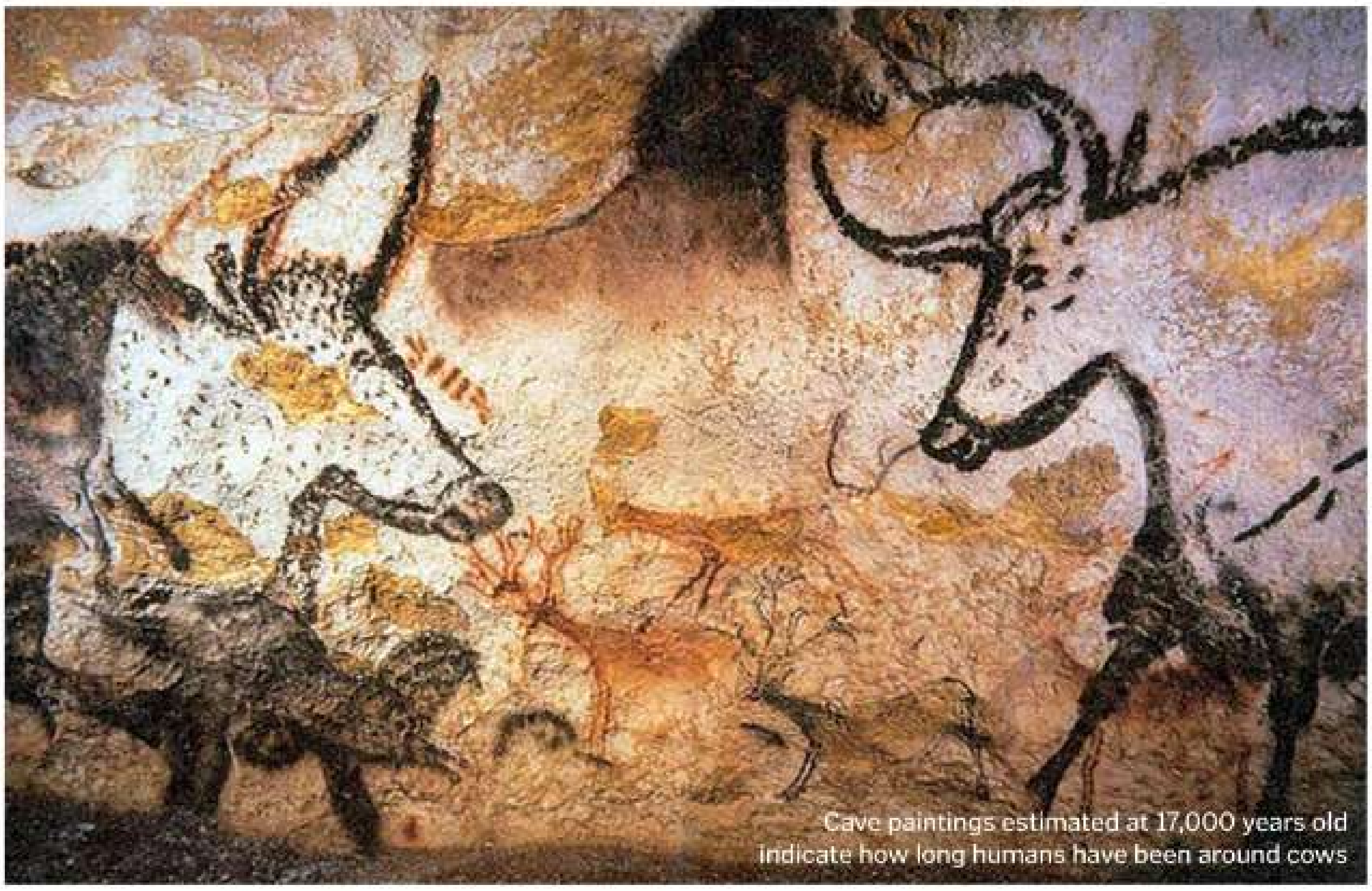
HOW COWS ARE CHANGING THE WORLD

With over a billion cows populating our planet, what is the impact of thousands of years of bovine breeding?

Words by **Ailsa Harvey**





Cave paintings estimated at 17,000 years old indicate how long humans have been around cows

Source: Wiki/Prof saxx

Cows have been providing products for us for millennia, and are more useful to us than any other farm animal. We encounter cow products every day, whether that's eating a beef burger, putting milk in our tea or wearing a leather jacket.

Widespread across the globe, cow species have been bred in vast numbers, with unique characteristics to suit their environment and cater for the world's population. Their incredible versatility makes them a staple of our diet, contributing to around 24 per cent of all meat consumption.

Approaches to cow farming differ greatly depending on location, as well as the conditions cows face. As the world's biggest dairy producer and consumer, India is home to millions of sacred cows. They roam the streets in the subtropical heat and provide products to the people. Meanwhile, winters are so long and hard on one Russian dairy farm that the farmer provides cattle with a taste of the ultimate paradise: cows on this farm wear virtual reality headsets that project scenes of lush pastures and balmy sunshine. The Moscow farm adopted this approach after research showed a link between a cow's emotional experience and the quality of its milk production.

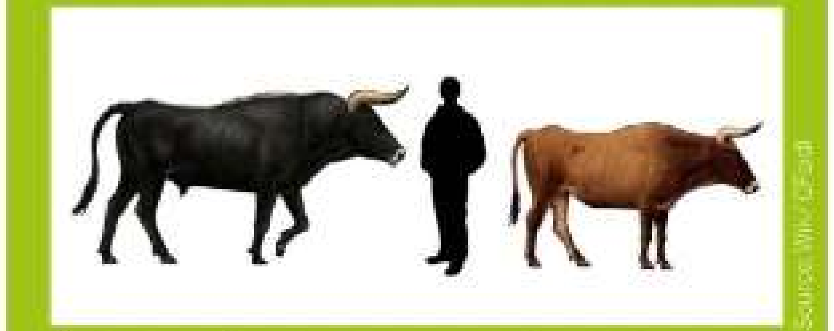
Animal agriculture has come a long way – especially for cattle. The abundance of bovines we see in our fields today are the result of thousands of years of breeding. Originally stemming from a group of as little as 80 animals, this drastic increase in population has inevitably impacted the environment over time. But is this for the better or worse?

The environmental consequences of cattle farming range from the detrimental effects on the ozone layer that a billion cows passing digestive gases has to the change in landscape and removal of trees in the creation of farm-friendly areas. Cattle farming generates income for millions of farmers, though many aim to achieve more sustainable farming. A useful by-product of cattle, manure can be used as fertiliser, soil amendment and even for construction. High in nutrients and energy, it is valued as a renewable source on many farms.

Domesticating huge herbivores

As one of the first animals domesticated by humans, our encounters with cows can be traced back to ancient times. Having domesticated five wild cattle species in the last 10,500 years, early cattle were strikingly different. Now extinct, aurochs were much taller than the cows you would find in our fields today and boasted impressively long horns. As some of the largest herbivores in Europe, these bulls reached up to 1.8 metres – significantly larger than the breeds of today.

Evidence of the importance of cattle to some of our early ancestors can be found in cave paintings, clearly depicting ancient cows and humans' interest. Across the history of cow domestication, the diversity of species in different environments can determine where their domestication took place. Areas where domestication started, such as in India and Europe, usually have a bigger range of breeds. Places where cattle were brought following their domestication have limited diversity, as breeding only between the already-domesticated cattle has taken place.



Source: Wiki/ CFazil

Illustration showing size comparison between aurochs and the bulls of today

In more recent times, the industry has been put under more scrutiny than ever before as people question the impact of dairy farming and its significant contribution of greenhouse gases. As the world's population continues to increase, food production also rises. Environmentalists continue to analyse the impact of our food sources – and animal agriculture is in the spotlight.

Cattle by country

How do breeds vary?

Indu-Brazil

BRAZIL

Indu-Brazil cows have humped backs and unique low-hanging long ears which allow them to better regulate body temperature.

© Shutterstock

Highland

SCOTLAND

To cope with Scottish weather, these hairy cows have a double coat – an oiled outer coat expels frequent rain and snowfall.

© Getty

Australian Charbray

AUSTRALIA

Bred in Australia as a cross between the Charolais and Brahman, the Charbray cope well in the hot and humid conditions.

Source: Wiki

Yakutian

SIBERIA

Yakutian cattle are bred north of the Arctic Circle, and are especially tolerant to freezing conditions. They have a thick coat.

Source: Wiki/ Anu Osva

Limousin

FRANCE

Originating between central and south France, Limousin cattle are acknowledged for their great ability to adapt to conditions.

© Shutterstock

How are cows impacting the environment?

From their inbuilt biology to human-made homes, cattle farms are leaving their mark

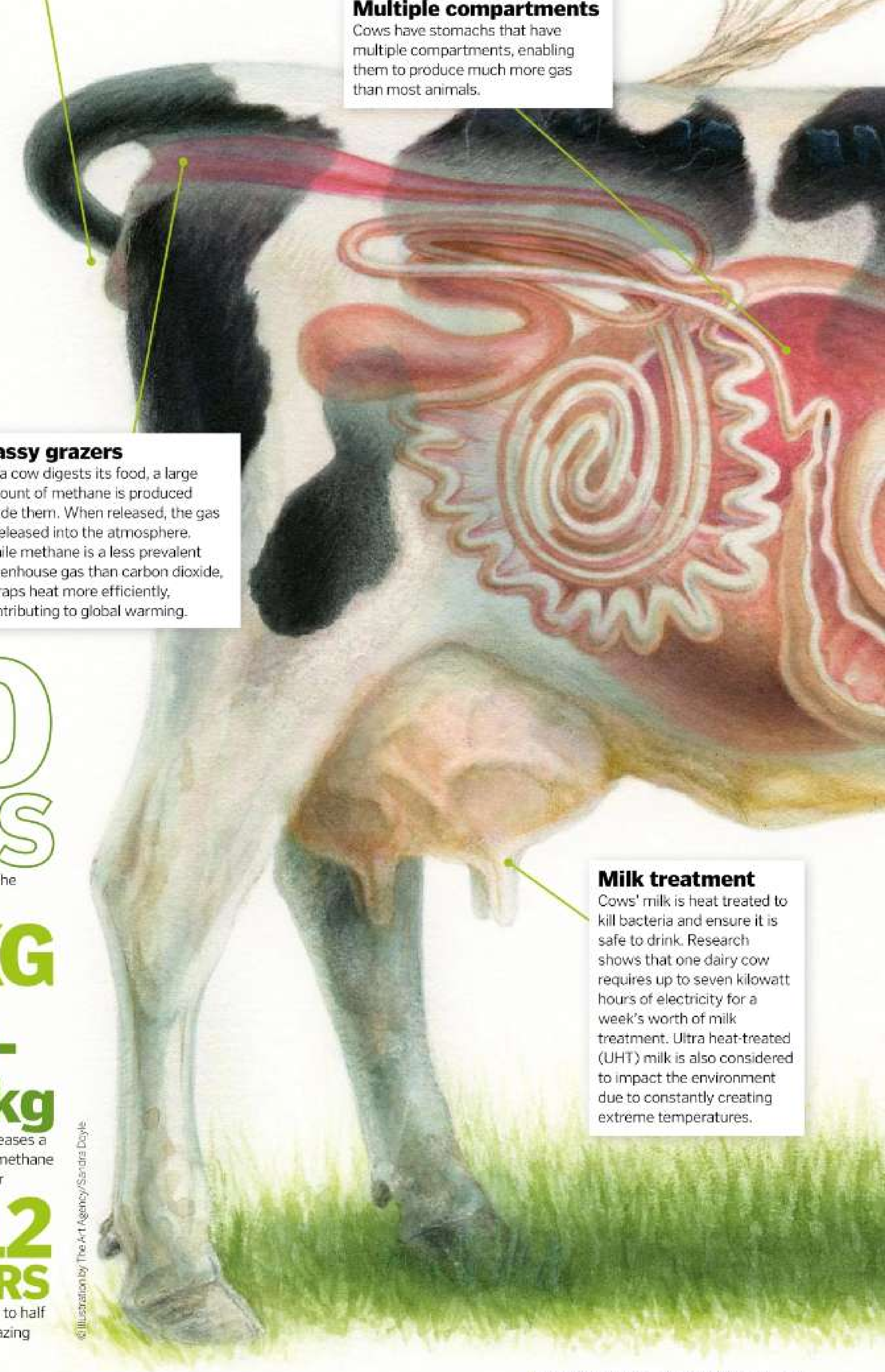
Heat-resistant dairy herds

Have you ever heard of a heat-proof cow? As a way to continue cow farming while attempting to accommodate for the threat of climate change, some Indian farmers have embraced the potential of miniature cows.

The Vechur cow is the smallest bovine in the world, and scientists think they could be the future if cow farming is to continue. Originating in Kerala, India, these species can withstand much greater temperatures than your average dairy cow. This was discovered during an intense heat wave across India, which saw the tiny cows continue to thrive while other cows struggled. Not only do they have the potential to live seemingly unphased by the warming planet, they also produce less methane than other cow species per unit of milk produced.

Source: Wiki/ [illegible]

The small Vechur cow has an average height of 87 centimetres



Waste in waterways

As well as the gas produced, cow manure impacts greatly on the environment. Often used as fertiliser, it can be carried with rainfall into rivers and lakes. High in phosphorus and nitrogen, the manure can turn the water green by increasing algae growth. This often ruins drinking water by creating toxins.

Multiple compartments

Cows have stomachs that have multiple compartments, enabling them to produce much more gas than most animals.

Gassy grazers

As a cow digests its food, a large amount of methane is produced inside them. When released, the gas is released into the atmosphere. While methane is a less prevalent greenhouse gas than carbon dioxide, it traps heat more efficiently, contributing to global warming.

Milk treatment

Cows' milk is heat treated to kill bacteria and ensure it is safe to drink. Research shows that one dairy cow requires up to seven kilowatt hours of electricity for a week's worth of milk treatment. Ultra heat-treated (UHT) milk is also considered to impact the environment due to constantly creating extreme temperatures.

© Illustration by The Art Agency/Sandra Doyle

30%

Nearly a third of Earth's surface is used for livestock farming

95%

Most methane produced comes from cows' mouths

230 LITRES

A cow's main stomach can hold the equivalent of a full bath

11 BILLION KG

A huge amount of beef was produced by the US in 2009 alone

340 MILLION TONNES

3.4 per cent of global carbon emissions are caused by deforestation for cattle ranching

70-120kg

A single cow releases a huge amount of methane every year

8-12 HOURS

Cows spend up to half their days grazing

The black-and-white Holstein Friesian cow became popular to breed due to their ability to produce more milk

© Getty

Lots of 'rumen' there

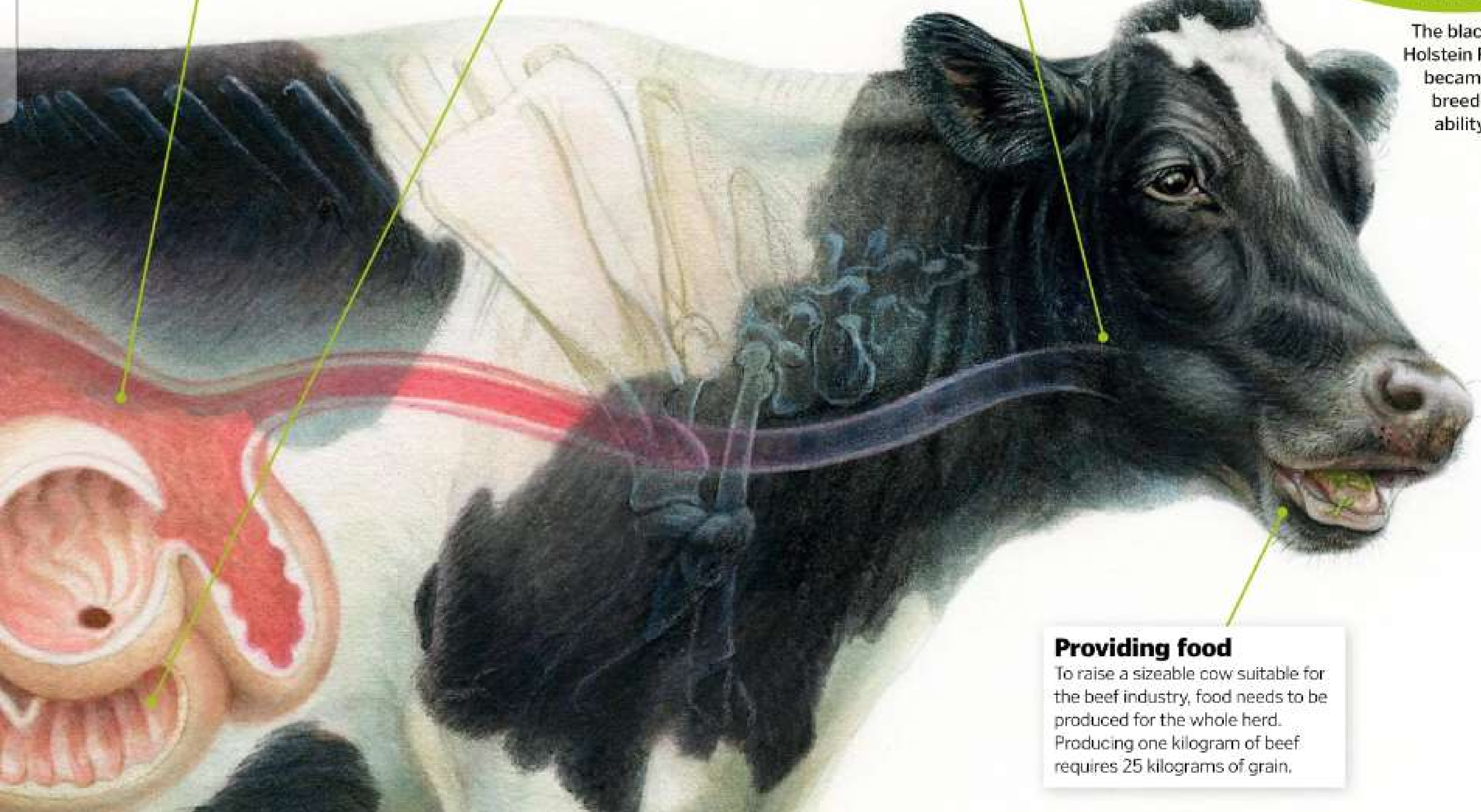
The rumen is the largest of their stomach's compartments. It can hold over 200 litres of material and contains millions of microbes.

Wasted production

Over 30,000 tonnes of beef goes to waste in UK houses alone. A waste of food is also a waste of all the resources put into its growth.

Water footprint

Like in all food production, water is required. Nearly 16,000 litres of water is needed to produce just one kilogram of beef.

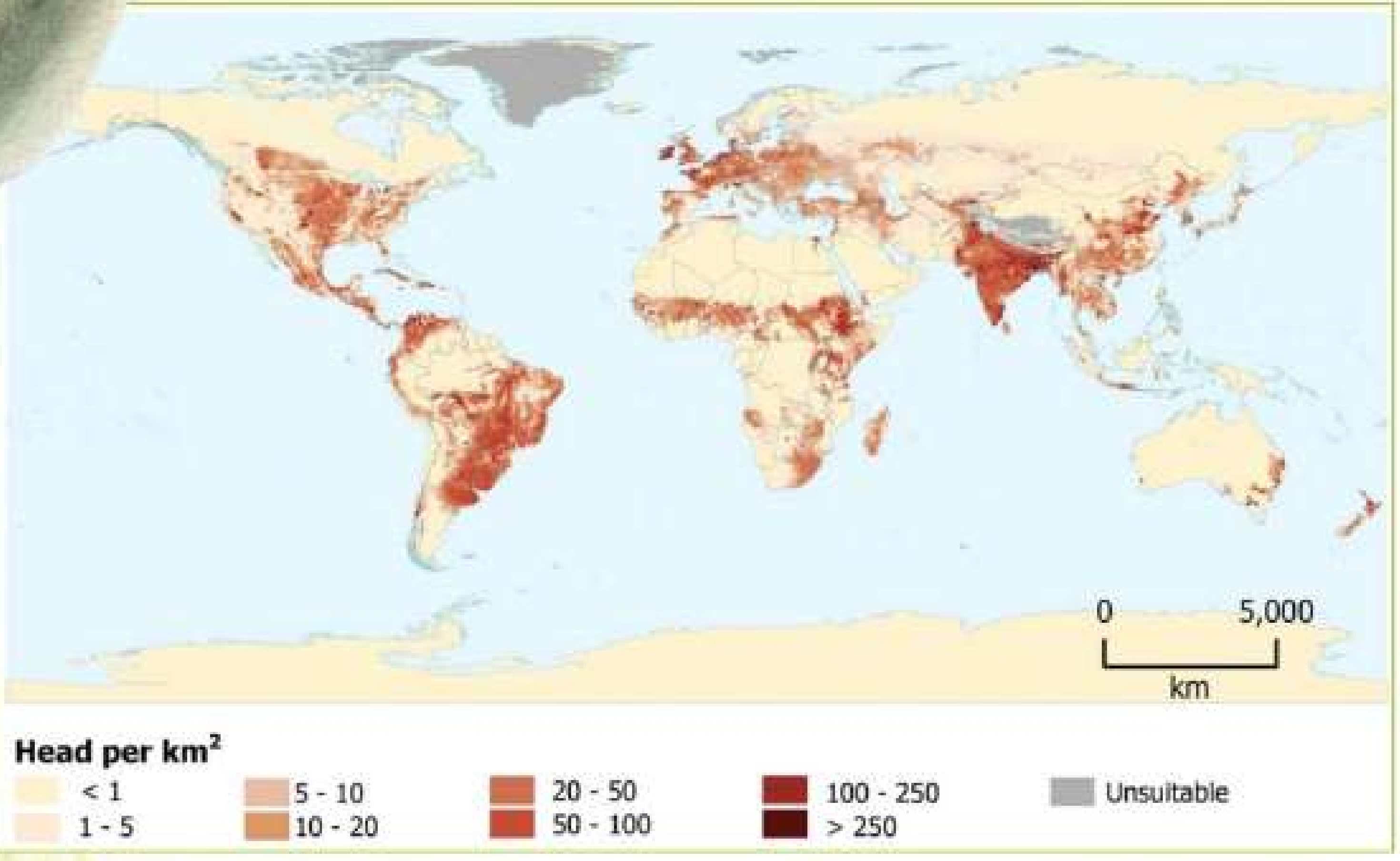


Providing food

To raise a sizeable cow suitable for the beef industry, food needs to be produced for the whole herd. Producing one kilogram of beef requires 25 kilograms of grain.

Creating space

Significant areas of land need to be cleared to allow cows to graze. This results in the loss of habitat for animals, reducing biodiversity. 80 per cent of deforestation is thought to be caused by cattle farming.



© Livestock Geo-wiki

Where's the beef?

10,000 years ago, domesticated cows were found in two locations: one in India and one in Europe. Now these animals roam all continents except Antarctica, with countries such as Brazil and New Zealand being home to more cattle than people. Take a look at where most of Earth's cows live on the global distribution map above.

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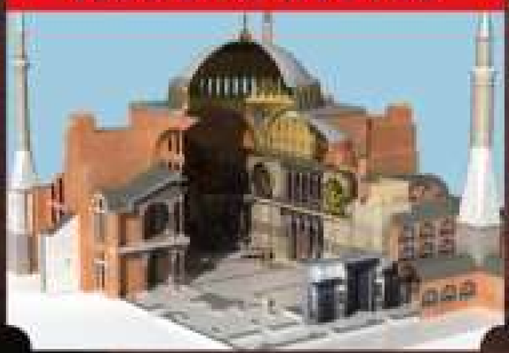

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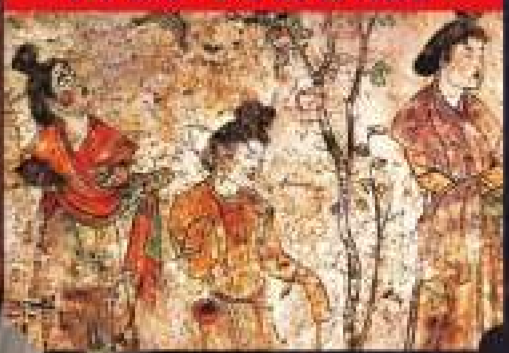

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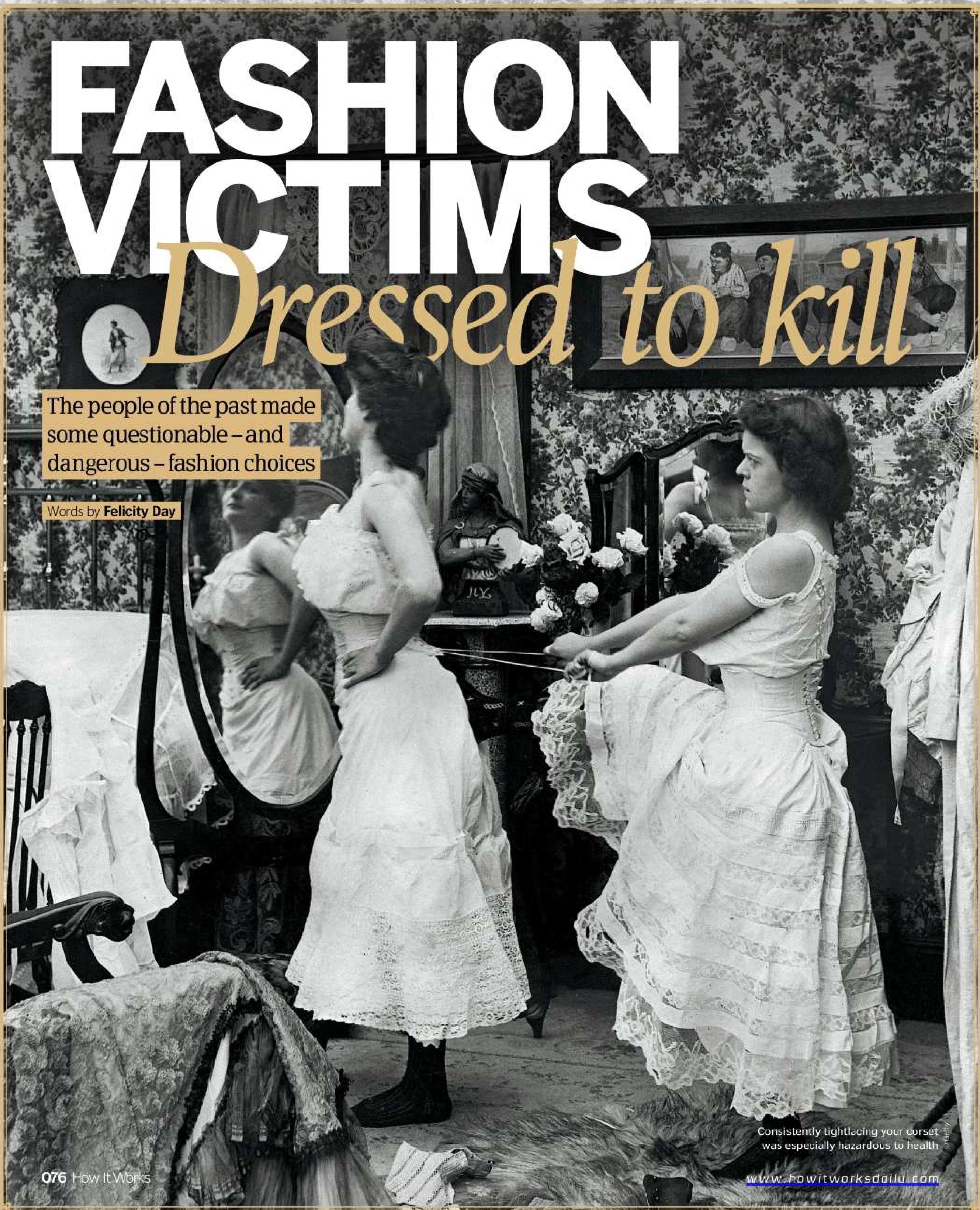
FASHION VICTIMS

Dressed to kill

The people of the past made some questionable – and dangerous – fashion choices

Words by **Felicity Day**



Consistently tightlacing your corset was especially hazardous to health

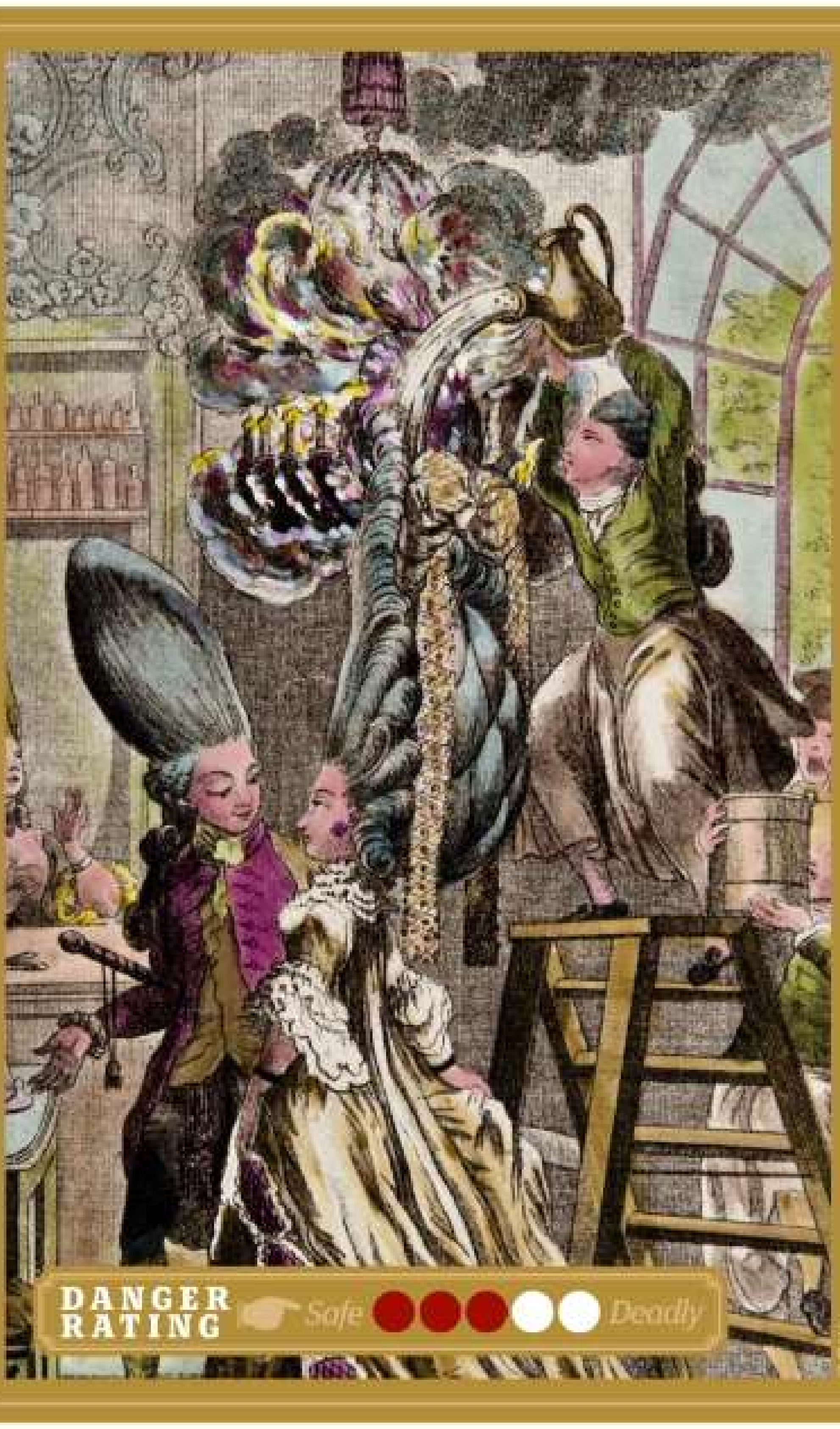
© Getty

Today 'dressed to kill' has a rather different meaning, but in centuries past what you chose to wear could very easily determine how you died. From gowns coloured with poisonous pigments to tight shirt collars that choked them, the clothing our ancestors put on made fashion victims of them, quite literally. Take the corset, for example. Victorian women from socialites to shop girls used the cinching undergarment to achieve the tiny waist that was then the feminine ideal – despite the fact that it inhibited their movement and came with numerous health hazards. While these could be as mild as chronic indigestion, the use of corsets did carry a very real risk of death: if a steel stay snapped, it could easily puncture a woman's internal organs.

Of course, the necessity of using open fires and candle flames for heating and lighting was behind a significant number of the clothing-related deaths of times past. But though our domestic environments have fewer fire hazards today, contemporary fashion trends do still have their perils: the crazes for platform shoes in the 1970s and 1990s, for example, were blamed for rising car accidents, as the super-sized soles were found to slow braking speeds and therefore increase car stopping distances. A 2011 US study also found that there's toxic lead content in some of our most popular brands of lipstick. So beware: deadly fashion is not yet consigned to the history books.

Big wigs

The mid-18th century vogue was for extremes: big dresses and even bigger hair. Towering wigs were hot and heavy to wear, causing sores on the scalp, and they were easily set alight, especially as the hair powder used for whitening and lard for styling made them highly flammable. And there were other reported dangers: long wire pins holding up a lady's lofty coiffure acted like a lightning conductor during a storm in 1778, setting it ablaze and singeing her face. Infestations of lice (or worse, mice) were a persistent problem, since the elaborate hairpieces usually went unwashed for weeks.

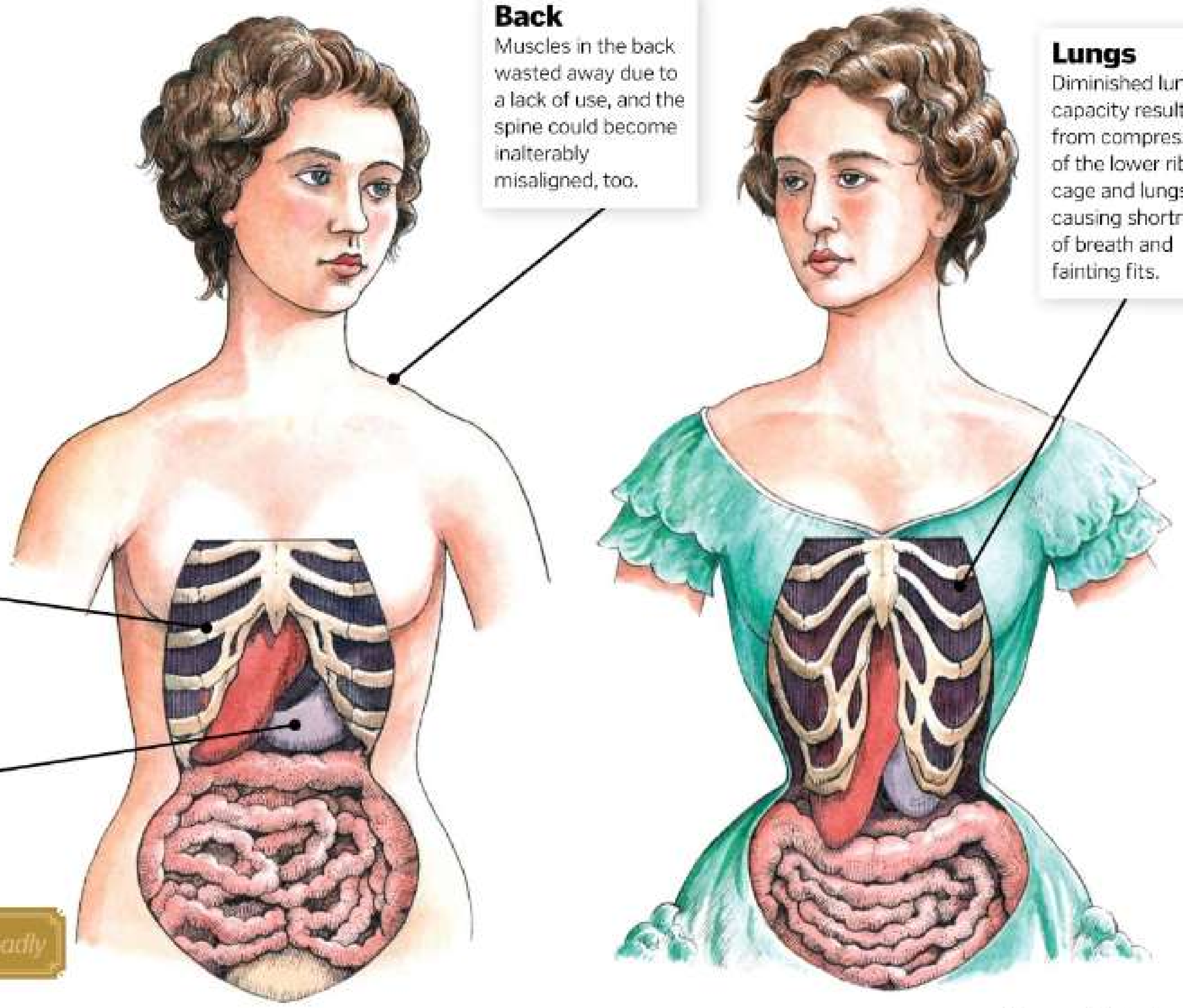


DANGER RATING Safe ●●●○○ Deadly

Mocked by the press, towering wigs were highly flammable and attractive to vermin

Constricting corsets

Though it successfully cinched the waist, a corset put untold pressure on a woman's body



Back
Muscles in the back wasted away due to a lack of use, and the spine could become inalterably misaligned, too.

Lungs
Diminished lung capacity resulted from compression of the lower rib cage and lungs, causing shortness of breath and fainting fits.

Rib cage
Ribs were pushed up and inwards, becoming permanently deformed over time and causing internal organs to shift or change shape.

Stomach
Indigestion and constipation were the result of constant constriction of the stomach and intestines.

DANGER RATING Safe ●●●●○ Deadly

© Illustration by The Art Agency/ Peter Scott

Explosive hair combs

An early form of plastic, celluloid, began to be used to make decorative hair combs in the late 19th century as a cheaper and more animal-friendly alternative to the traditional ivory. But its chemical composition – particularly in cheaper varieties – made it acutely sensitive to heat, so simply sitting near to the fire or using curling tongs could cause a comb to self-ignite – and even explode! They gave women scalp burns and patches of permanent hair loss, and when placed in shop windows in the glare of the Sun, they sent retailers' window displays up in flames after combusting.

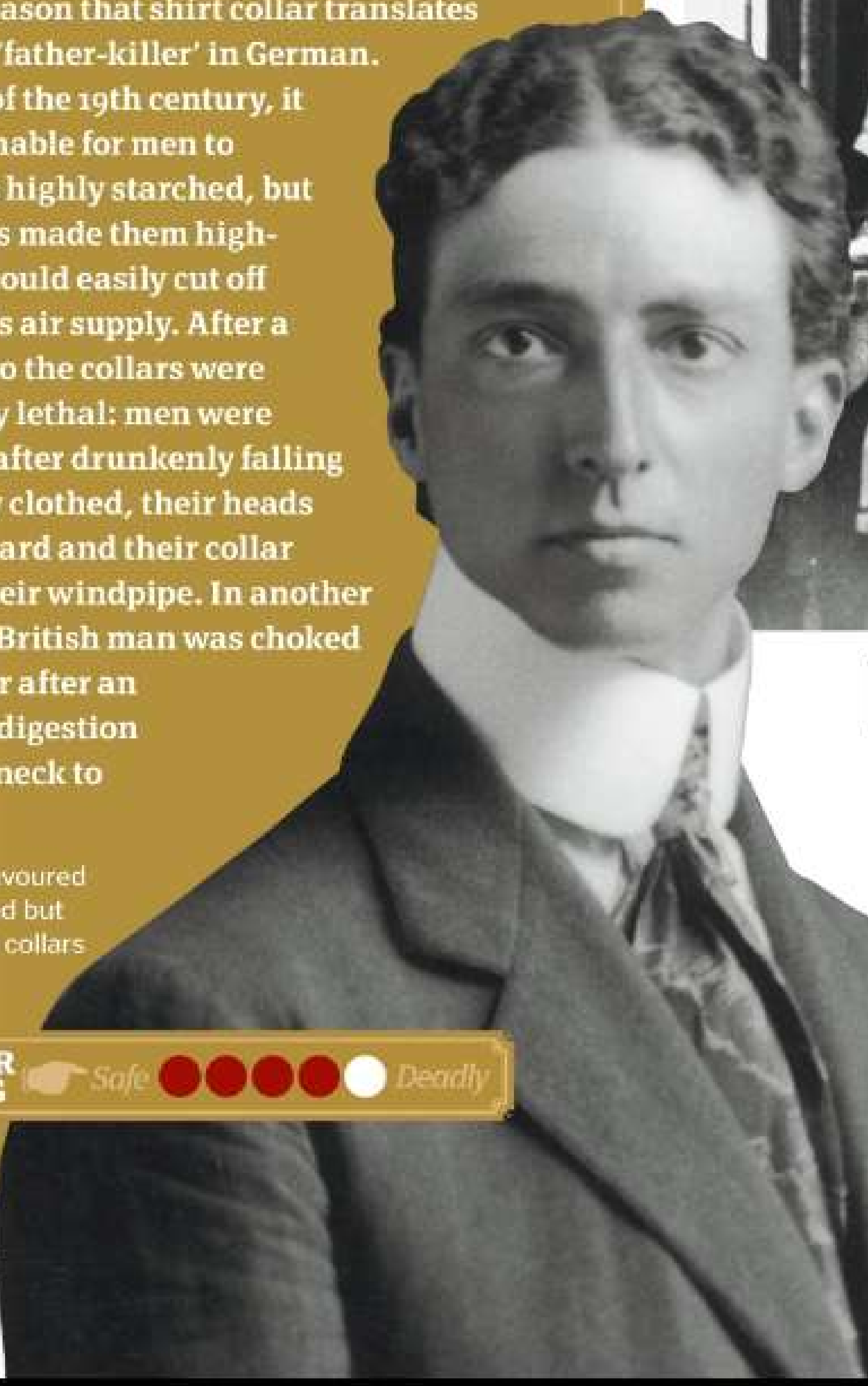
© Getty

Celluloid was used as an ivory substitute in all manner of accessories

DANGER RATING Safe ●●●●○ Deadly

Choking collars

There's a reason that shirt collar translates literally as 'father-killer' in German. At the end of the 19th century, it was fashionable for men to wear theirs highly starched, but the stiffness made them high-risk. They could easily cut off the wearer's air supply. After a tipple or two the collars were particularly lethal: men were suffocated after drunkenly falling asleep fully clothed, their heads tilting forward and their collar stopping their windpipe. In another incident, a British man was choked by his collar after an attack of indigestion caused his neck to swell up.



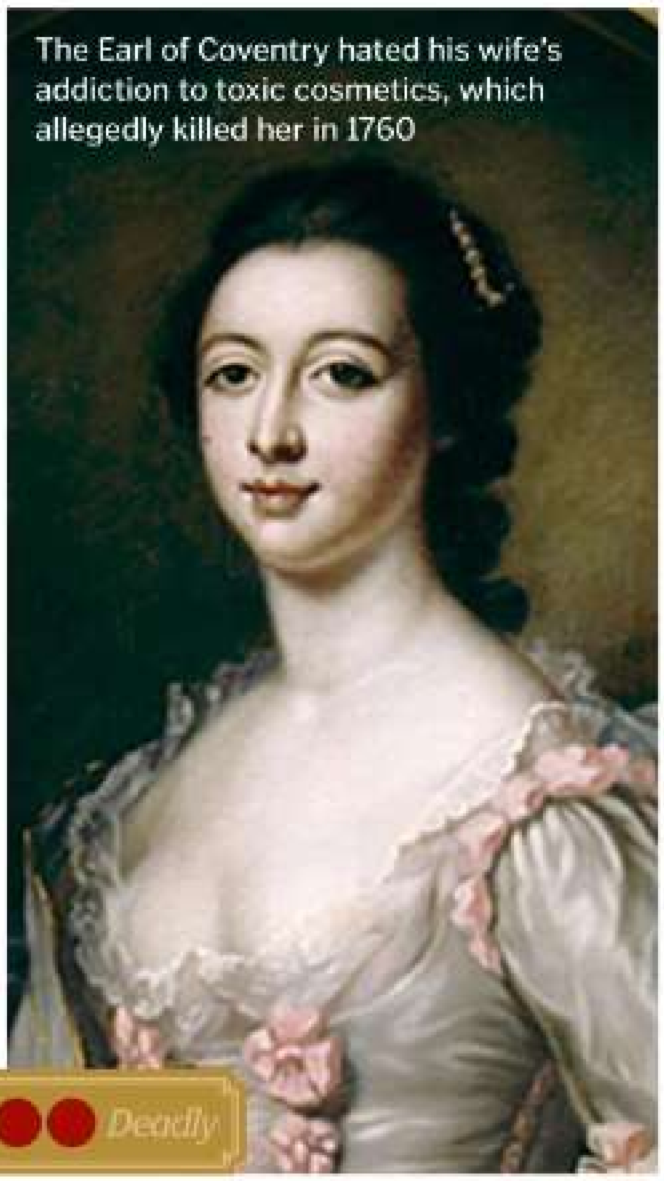
Stylish men favoured highly starched but high-risk shirt collars

DANGER RATING Safe ●●●●○ Deadly

© Getty

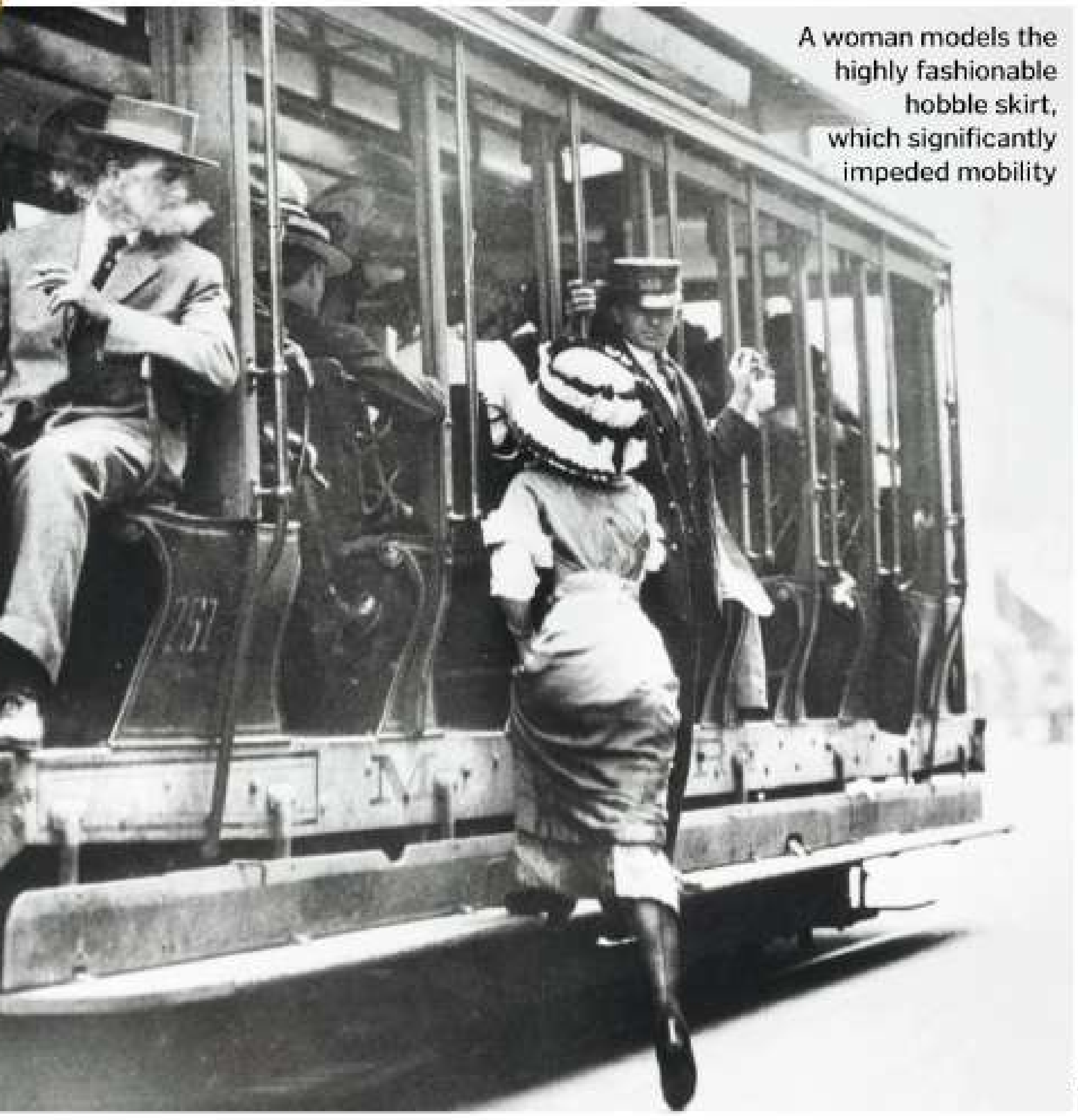
Toxic make-up

Today we favour a healthy sun tan, but until the late 18th century a pale complexion was highly prized – it was a sign that you were too wealthy to be labouring outdoors. Lead-based make-up, mixed up with vinegar or manure, gave skin the desirable porcelain-white tint, but it corroded it too, causing facial sores. It also dried skin out, causing wrinkles. More worryingly, it slowly poisoned the wearer, who would suffer hair and tooth loss, headaches, muscle paralysis and mood swings before the exposure killed them. Some suspect blood poisoning caused by toxic face paint led to Elizabeth I's death – she had used it religiously to conceal her smallpox scars.



The Earl of Coventry hated his wife's addiction to toxic cosmetics, which allegedly killed her in 1760

DANGER RATING Safe ●●●●● Deadly



A woman models the highly fashionable hobble skirt, which significantly impeded mobility

© Getty

Hobble skirts

The Edwardian era saw women favouring increasingly narrow and clinging skirts, but the trend took a treacherous turn with the hobble skirt. Tightly cinched in at the knees and ankles, wearers were essentially crippled, able to take only tiny, tottering steps. They frequently toppled over, hitting their heads on pavements, breaking their legs and worse. In 1911 a woman drowned after a stumble caused her to plunge over a low railing into a canal below.

DANGER RATING Safe ●●●○○ Deadly

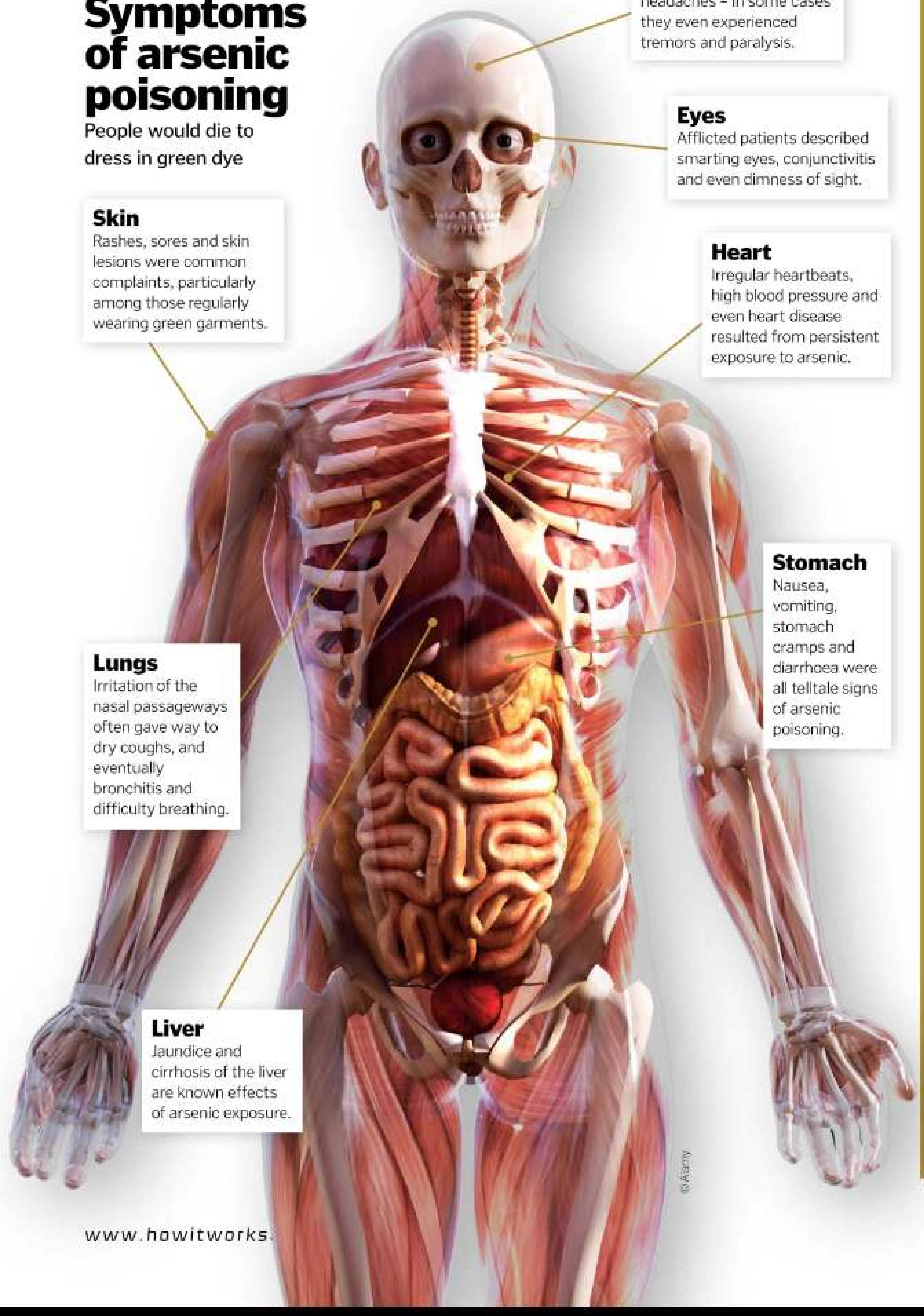
Poisonous pigments

Green dye had been notoriously difficult to create, so when Carl Scheele's chemically produced pigment hit the market in the 1770s it was an instant success. Scheele's Green, along with the similar Emerald Green, became the most fashionable hue for dresses, gloves, hats and headdresses. But thanks to the use of arsenic in its production, green-tinted garments were incredibly toxic: just one gown could contain around 900 grains of the poison, shedding around 60 every time a woman waltzed her way through a single evening party. A lethal dose was just four or five grains! Similarly, a headdress of artificial foliage of the kind favoured by Queen Victoria contained enough arsenic to poison 20 people. Women who went wild for green weren't just endangering themselves, but everyone around them too.

DANGER RATING Safe ●●●●○ Deadly

Symptoms of arsenic poisoning

People would die to dress in green dye



Brain
Sufferers reported fatigue, fainting fits and persistent headaches – in some cases they even experienced tremors and paralysis.

Eyes
Afflicted patients described smarting eyes, conjunctivitis and even dimness of sight.

Skin
Rashes, sores and skin lesions were common complaints, particularly among those regularly wearing green garments.

Heart
Irregular heartbeats, high blood pressure and even heart disease resulted from persistent exposure to arsenic.

Stomach
Nausea, vomiting, stomach cramps and diarrhoea were all telltale signs of arsenic poisoning.

Lungs
Irritation of the nasal passageways often gave way to dry coughs, and eventually bronchitis and difficulty breathing.

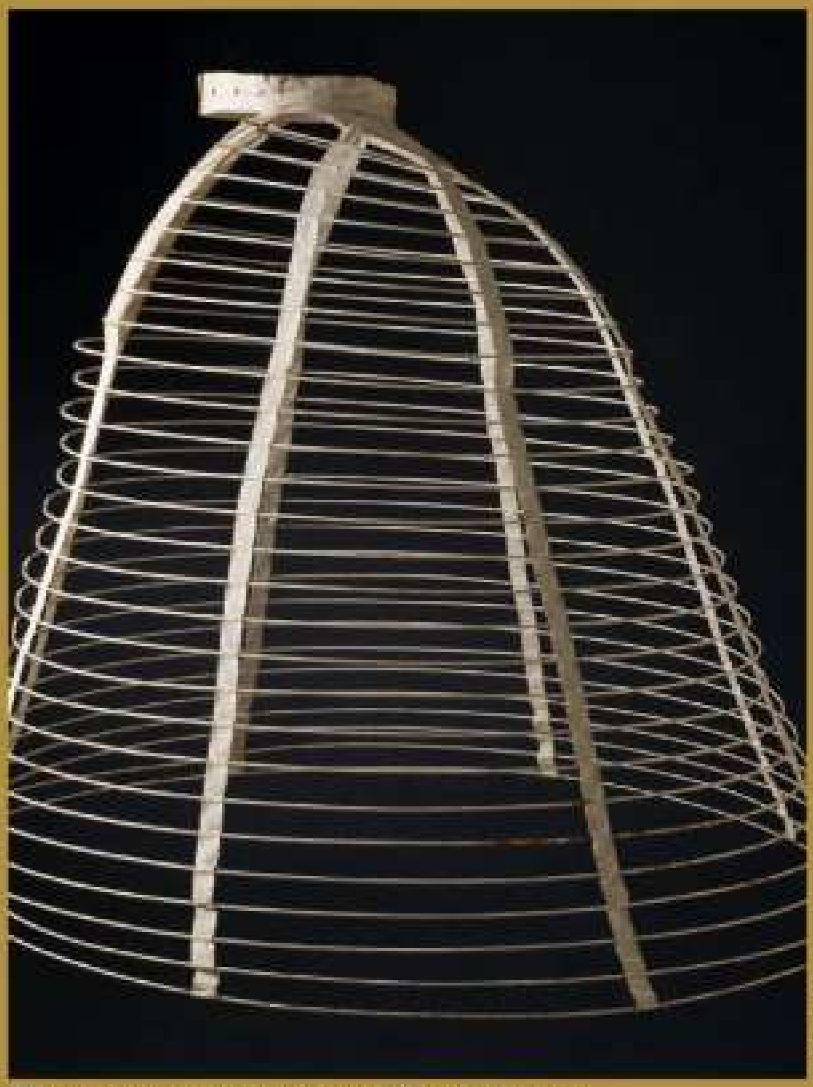
Liver
Jaundice and cirrhosis of the liver are known effects of arsenic exposure.

© Alamy

Combustible crinolines

Underneath the voluminous dresses beloved by Victorian women was a crinoline, a circular steel cage that gave the gown its structured shape. But it was deadly. It made their highly flammable muslin and silk skirts unwieldy in size and far more likely to brush against candle flames or fireplaces. And if the skirt ignited, the crinoline acted like a chimney, dramatically increasing the speed with which the fire spread. The huge hoops caused women to blow over cliffs and piers in gusty winds too, and trapped them in industrial machinery and carriage wheels.

DANGER RATING Safe ●●●●● Deadly



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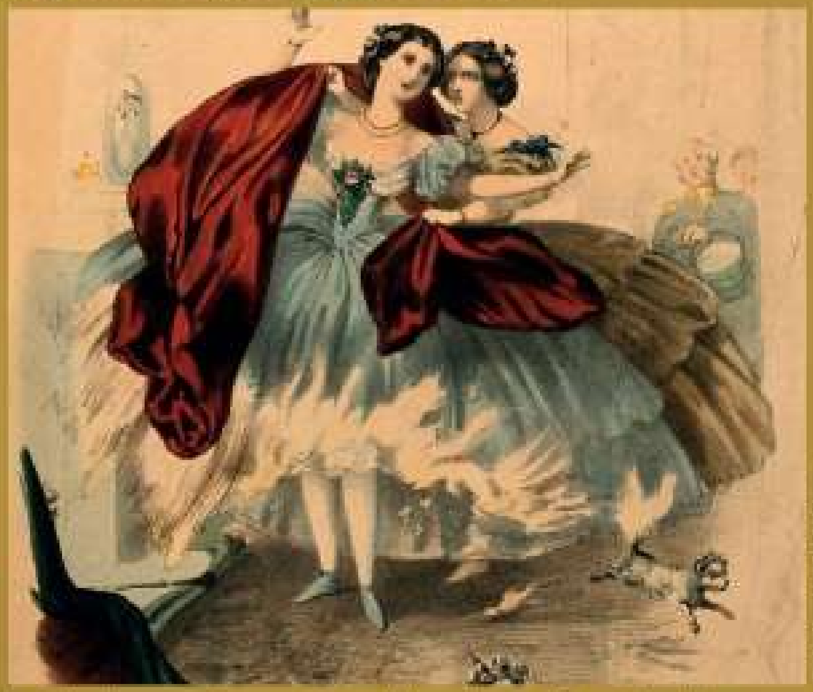
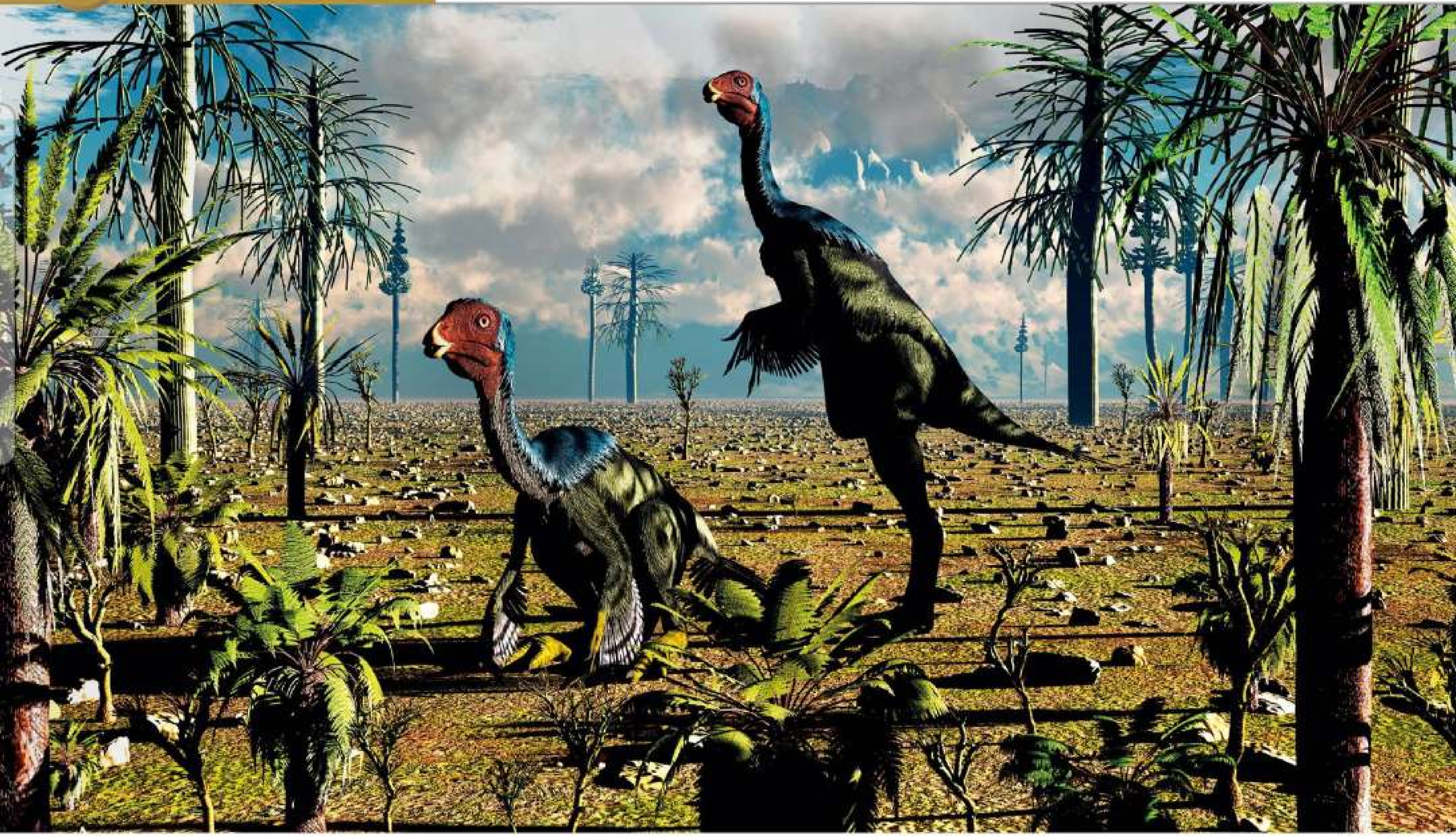
The cage crinoline replaced bulky layers of petticoats under women's dresses



© Wellcome Collection

Ladies' magazines advised keeping a 'fire cloak' in the house to extinguish an accidental blaze



© Getty

How the first feathered dinosaur lived

Discover Caudipteryx, the peacock-like dinosaur that roamed the lands of Asia 125 million years ago

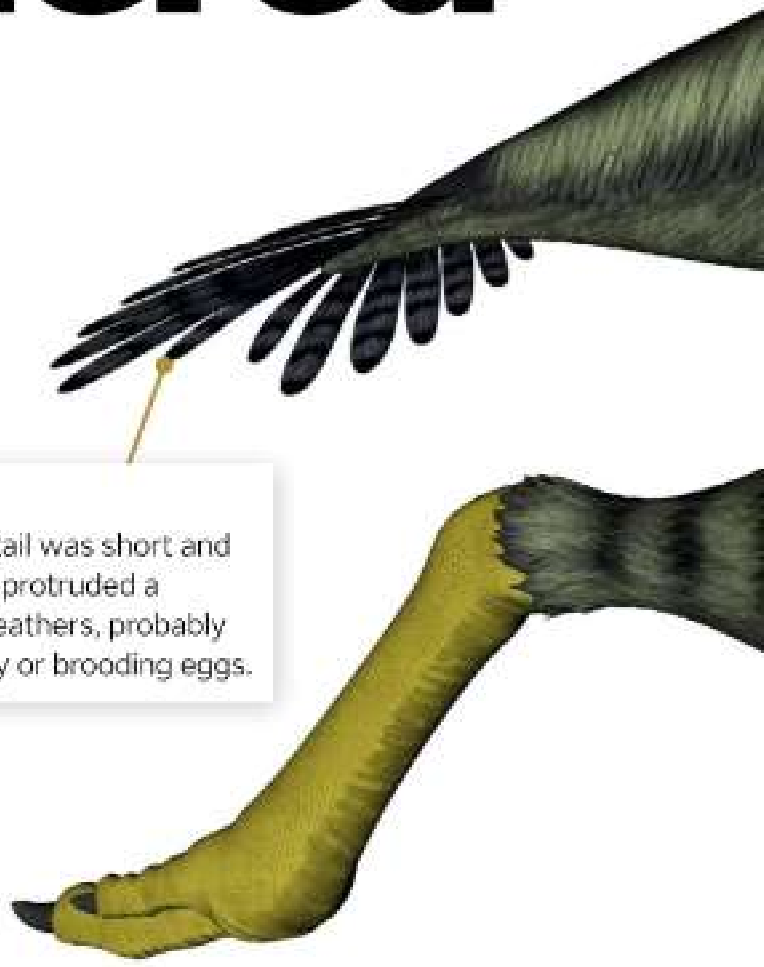
Words by **Ailsa Harvey**

In a time when dinosaurs inhabited the Earth, some colossal creatures towered at nearly 20 metres tall – causing the ground below to shake as they browsed for their food. But taking a look nearer the ground, a very different dinosaur lived below these beasts.

Meet the Caudipteryx, a group of curious-looking dinosaurs only discovered by humans in 1997. Estimated to have lived between 125 to 122 million years ago, the bird-like beings were equipped with long feathers at the end of their arms and tail. While images depict feathered wing-like arms, these would have been too short to be used in flight – this dinosaur spent its days running across the land.

There were two known species within the Caudipteryx genus: zoui and dongi. The zoui species were slight creatures with an estimated weight of just eight kilograms, with relatively long legs and short arms. The dongi were even smaller, and had proportionally less wing. However, it is the tail that gives Caudipteryx its name. The elaborate tail is thought to have been used for display, and detailed analysis into remains shows that they were likely to have been vibrant in colour. Translating 'Caudipteryx' to English, its name simply means 'tail feather'.

In recent research involving a robotic dinosaur and similarly built ostriches wearing artificial Caudipteryx wings, it is believed that the running style of the dinosaur would have caused its wings to flap at the side of its body. This could have been an evolutionary precursor to flight in some of the planet's future birds. If this research is accurate, it suggests the need for some early dinosaurs to run before they could fly.



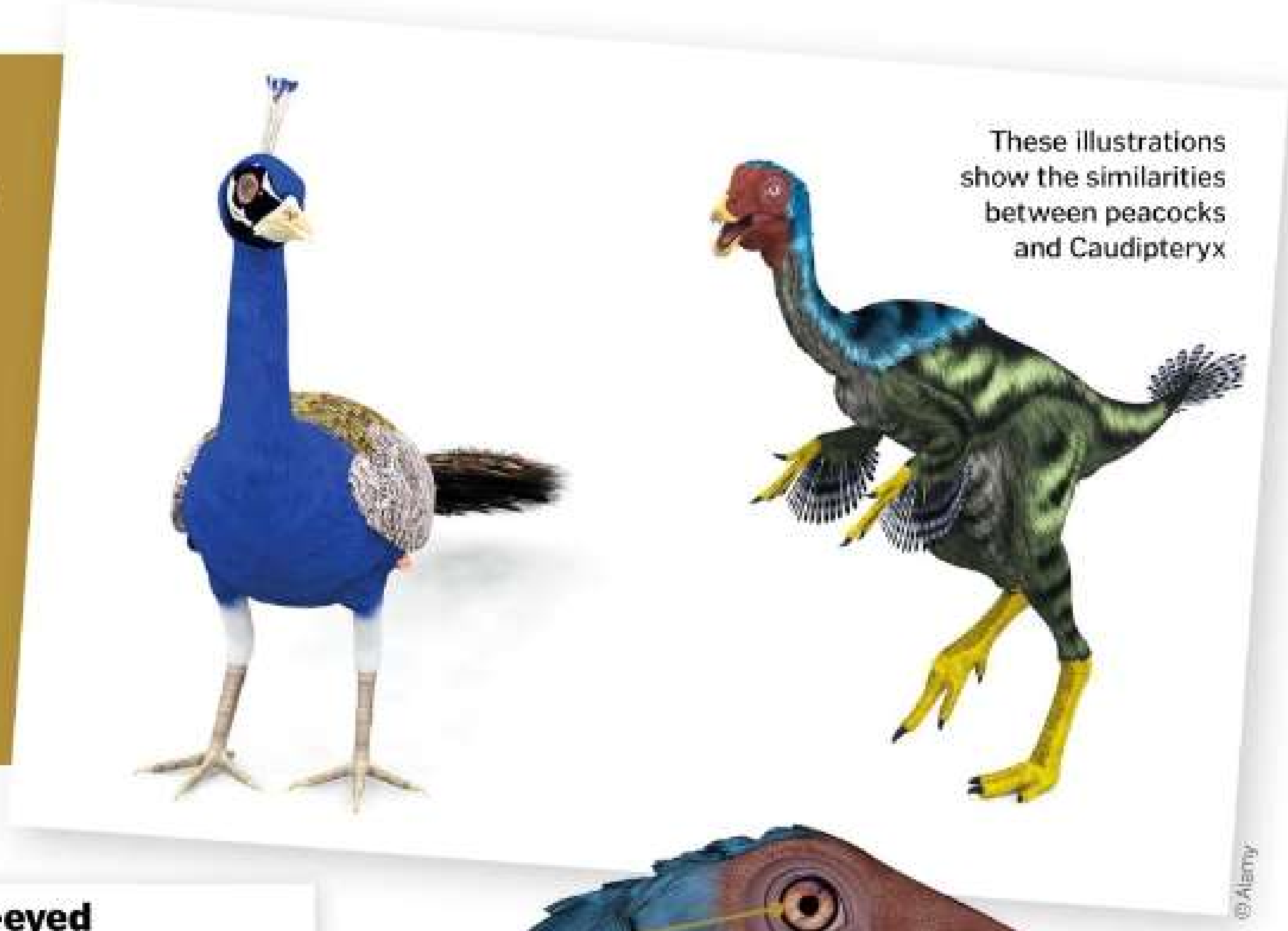
Tiny tail
Caudipteryx's tail was short and stiff. At its end protruded a unique fan of feathers, probably used for display or brooding eggs.

> "Analysis shows that they were likely to have been vibrant in colour"

Dinosaur or bird?

Visually, the Caudipteryx appears as a strange mix between bird and dinosaur, but how can we tell which it is? While their symmetrical long feathers are similar to those found on living flightless birds, they held different qualities to those of living and fossilised flying birds. Having analysed their long legs, scientists think that their lives were spent running. However, some have theorised that with their spaced-apart toes, they could have spent their time on Earth wading in water and mud, catching fish like some modern-day garden birds.

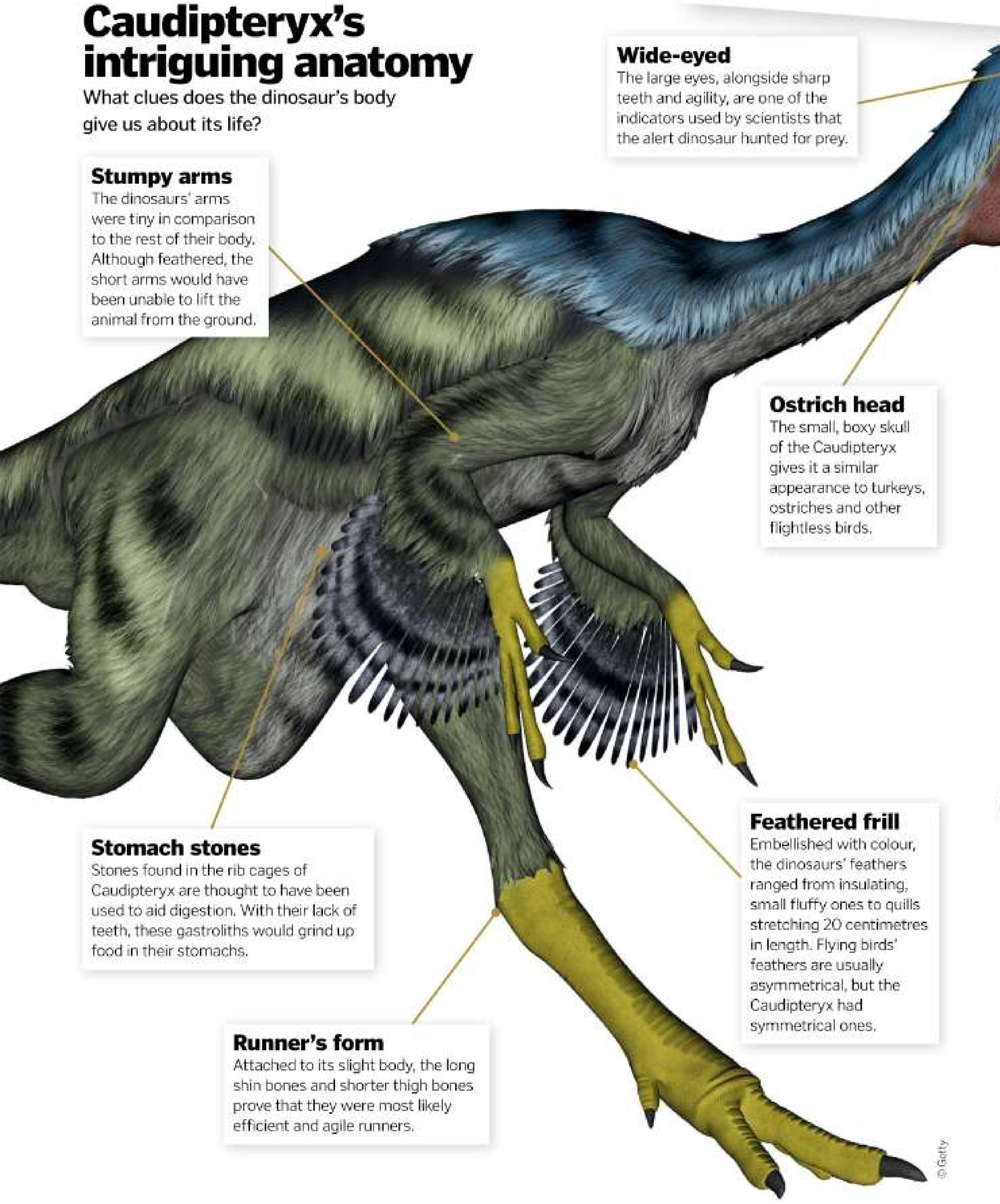
Having been classed as an 'Oviraptor' (Latin for 'egg-taker) – a group established in 1976 – Caudipteryx are in a subgroup of feathered dinosaurs. Animals in this group are thought by many to be the origin of birds. Their uncanny resemblance to birds is seen as a significant sign that they share some of the same ancestors.


These illustrations show the similarities between peacocks and Caudipteryx

© Alamy

Caudipteryx's intriguing anatomy

What clues does the dinosaur's body give us about its life?



Wide-eyed
The large eyes, alongside sharp teeth and agility, are one of the indicators used by scientists that the alert dinosaur hunted for prey.

Stumpy arms
The dinosaurs' arms were tiny in comparison to the rest of their body. Although feathered, the short arms would have been unable to lift the animal from the ground.

Limited teeth
Caudipteryx either had teeth on the upper jaw bones or none at all. Evidence of their teeth show them to be long and sharp. It is believed these teeth were used to eat plants and selected animals.

Ostrich head
The small, boxy skull of the Caudipteryx gives it a similar appearance to turkeys, ostriches and other flightless birds.

Stomach stones
Stones found in the rib cages of Caudipteryx are thought to have been used to aid digestion. With their lack of teeth, these gastroliths would grind up food in their stomachs.

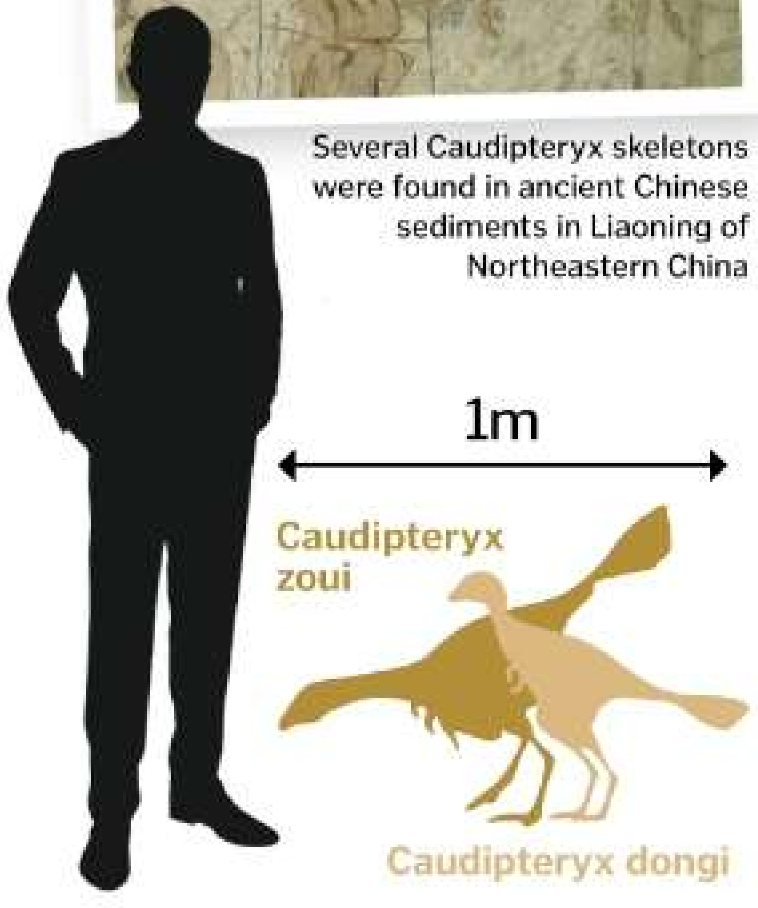
Feathered frill
Embellished with colour, the dinosaurs' feathers ranged from insulating, small fluffy ones to quills stretching 20 centimetres in length. Flying birds' feathers are usually asymmetrical, but the Caudipteryx had symmetrical ones.

Runner's form
Attached to its slight body, the long shin bones and shorter thigh bones prove that they were most likely efficient and agile runners.

© Getty

© Getty

Several Caudipteryx skeletons were found in ancient Chinese sediments in Liaoning of Northeastern China



The Caudipteryx grew to sizes no bigger than a peacock, reaching below half the height of most humans

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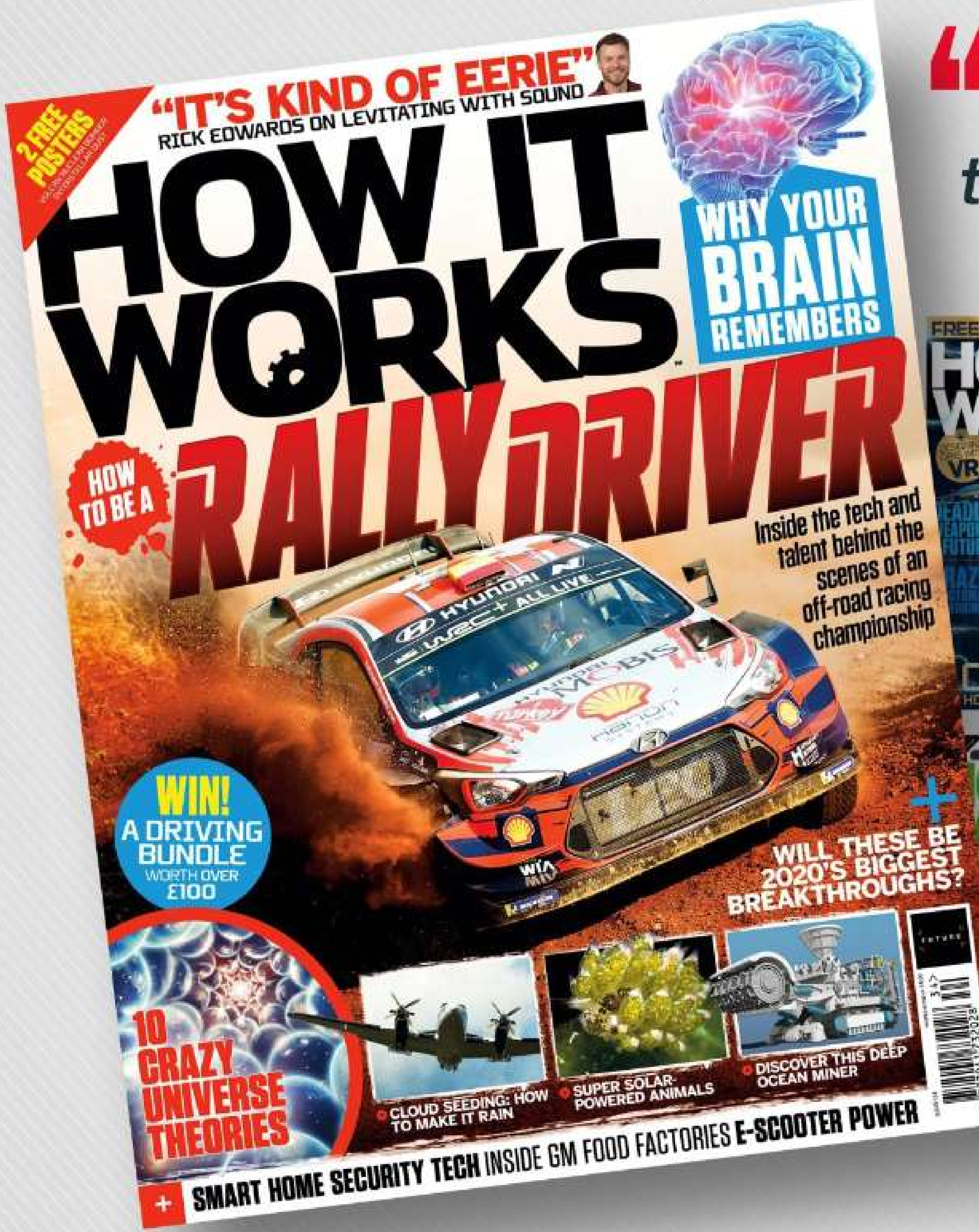
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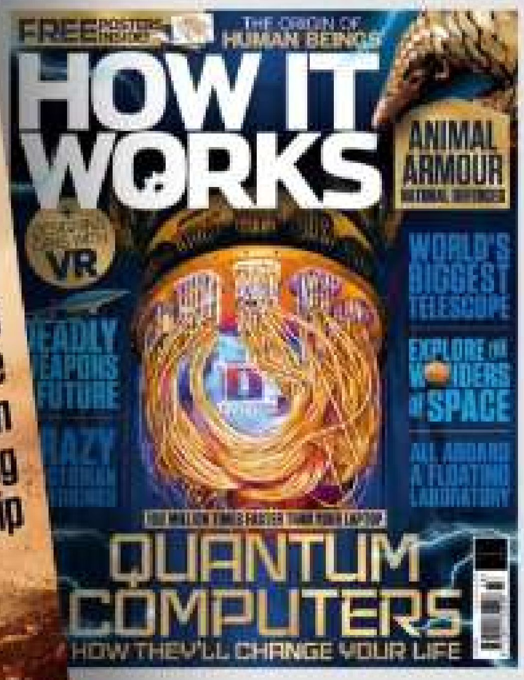
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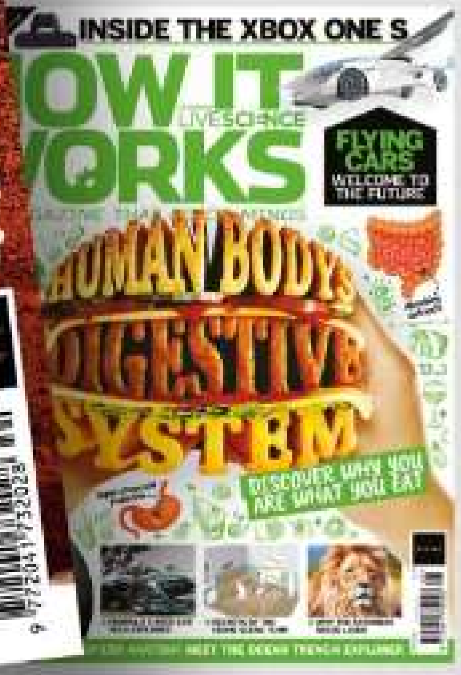
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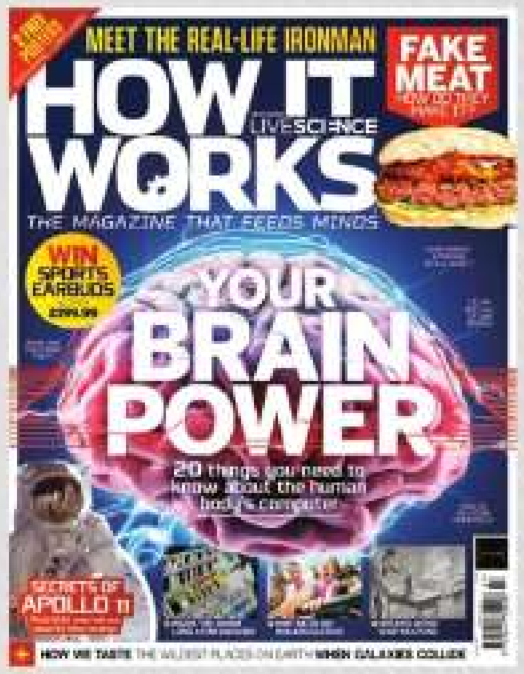
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Letter Jam
A COOPERATIVE WORD GAME

Letter Jam

Countdown, Heads-up!, Scrabble and even poker come together for a verbal twist on a guessing game

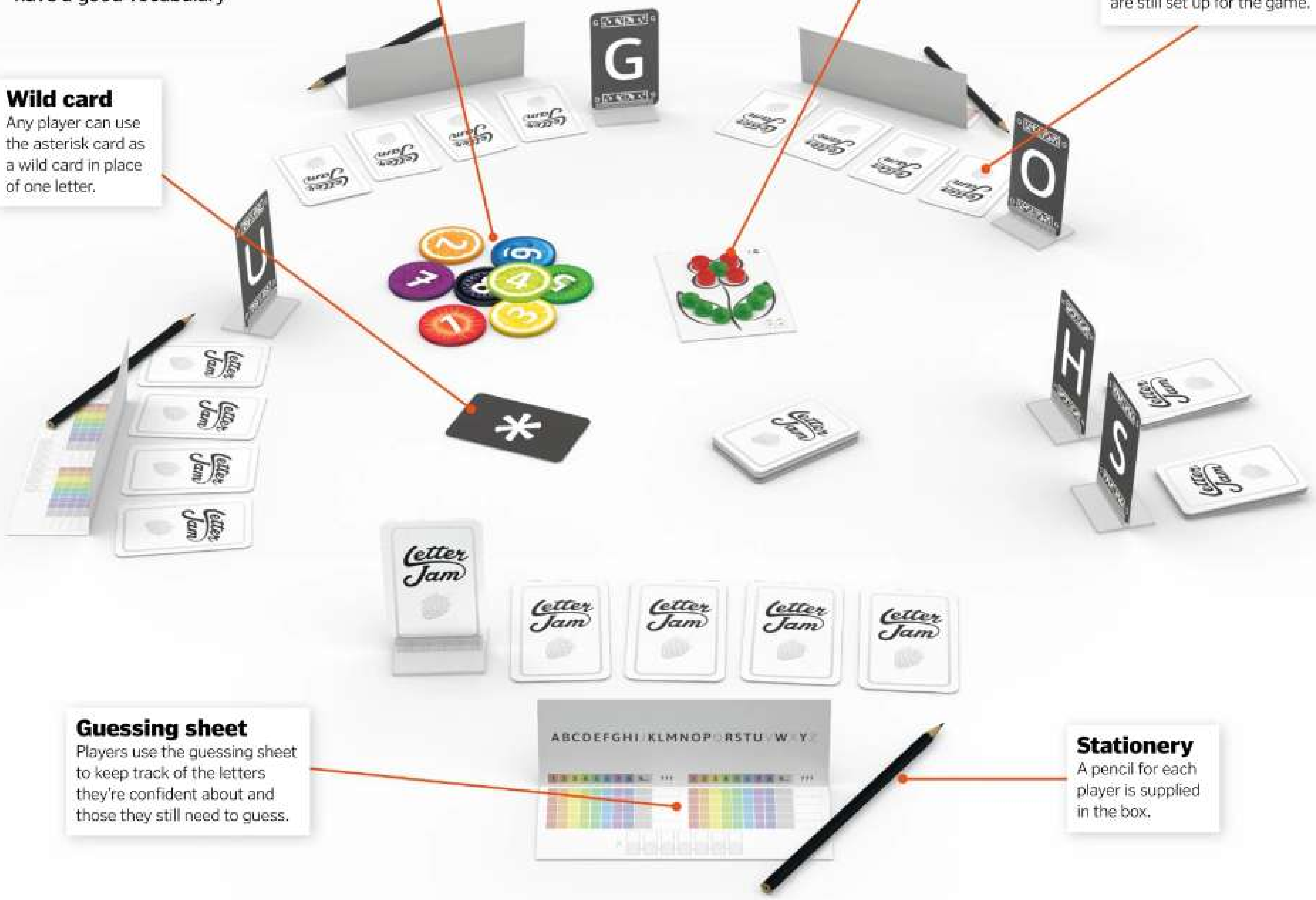
■ Publisher: **Czech Games** ■ Price: **£16.99 / $19.95** ■ Number of players: **2-6** ■ Recommended age: **10+** ■ Typical game time: **45 minutes**

This cooperative word guessing game involves players using the letter cards visible to them to form words. To begin, each player is given a certain number of cards face-down in front of them, as well as a card on a stand that all others can see, but they can't. The object of the game is to guess the face-down letters you have using the words that other players have spelled out, in a process of elimination and logic.

Each turn, all players try to spell as long a word as possible with the letters available to them, telling the other players the length of the word they've been able to spell, rather than the actual word. The player who can spell the longest word is the designated clue-giver. This player then gives numbered tokens to the players in the order that their letter comes in the word. Using this clue, each player then tries to guess what their letter is, putting the card face-down if they do and turning the next one up. The idea is to guess all the letters before the clues run out and the game ends. The more players that have unscrambled their hidden word, the more successful the team is. It takes a few runs to really get to grips with Letter Jam, and some of its rules are questionable in their inclusion, but with a scalable difficulty level there's a lot of replay value in it, especially for fans of Scrabble and its ilk.

We're jammin'

Letter Jam plays best with four players or more who have a good vocabulary



Letter ordering
These coloured tokens are placed by the designated clue-giver in the order that the player's letter comes in the word.

Give us a clue
You keep track of the number of clues using this card. The number of these tokens varies depending on the number of players.

Making up numbers
Even if there are only two players, the other four players are still set up for the game.

Wild card
Any player can use the asterisk card as a wild card in place of one letter.

Guessing sheet
Players use the guessing sheet to keep track of the letters they're confident about and those they still need to guess.

Stationery
A pencil for each player is supplied in the box.

© Asmodee

BRAIN DUMP

Because enquiring minds need to know...

Do planets made of metal exist?

Juan Hernandez

If the Earth was stripped of all the layers of rock, just leaving its nickel-iron core, it would be a metal planet itself. As it is, its composition is dominated by rock, and the same is true of most planets of a similar size. The closest to a 'metal planet' here in the Solar System is Mercury, which is 70 per cent iron by weight. At least one exoplanet – K2-229b – is known to have similar composition, but on a bigger scale. It's comparable in size to Earth, and considerably denser due to its large quota of heavy metals. **AM**

Mercury is the closest thing we have in the Solar System to a 'metal planet'

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MEET THE EXPERTS

Who's answering your questions this month?

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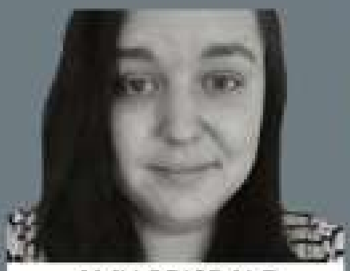

AMY GRISDALE

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Why does popcorn pop?

Rosa Blandford

■ Tiny water droplets inside popcorn kernels evaporate when heated up. The steam created ramps up the pressure so much so that the kernels burst open into a delicious treat. **AG**

It's not so much that plastic isn't recyclable – it's whether there's money in it

© Getty

Why isn't all plastic recyclable?

Diana Parker

■ In principle most plastics could be recyclable. Recyclers can do their jobs in various ways. In some cases they could just melt down certain types of used plastics and mould them into another form. Polyethylene terephthalate (PET) is cleaned up and ground into flakes, and then melted into a new shape. When that's not possible, recyclers might be able to break plastics down to their chemical building blocks and then reform the plastic molecules. The issue is mainly whether recyclers can sell their products at a profit. For example, recycling coloured plastics can be more costly. **AE**

Why do we get bags under our eyes when we are tired?

Hans Schmidt

■ Poor sleep can make blood vessels widen and look darker, and leak fluid into nearby tissue. Skin under our eyes is thin, so we easily see darkness and puffiness there. **AE**

© Getty

How do televisions work?

Aleksy Kowalski

■ Your TV captures broadcast signals and turns them into single images which are shown in such quick succession they appear to be moving.

Modern TVs, such as LCD, do this by switching tiny dots on their screen, or pixels, on or off to display a specific image. **MS**

© Getty

Elephants are able to remember directions to places they've been before

© Getty

Does an elephant really 'never forget'?

Matt Harvey

Elephants have incredible memory, but it might be pushing it to say they never ever forget. Elephants don't always perform perfectly in lab tests designed to test their memory, but can retain information for a seriously long time. Elephants recognise each other after decades of separation and remember their way to distant destinations year after year. **AG**

Why do canals have locks?

Sandra Myers

Canals don't naturally flow with the contours of the landscape, such as up and down hills. If we didn't have locks, narrow boats would essentially have to negotiate rapids in order to get from A to B.

Locks are 'chambers' where the boat sits. The doors are closed and the water level is lowered or raised to match the next part of the canal journey. The doors are opened and the narrow boat heads off. **MS**

Canal locks allow boats to navigate up and down the contours of the land via canal

Source: Joy of Film on Unsplash

© Getty

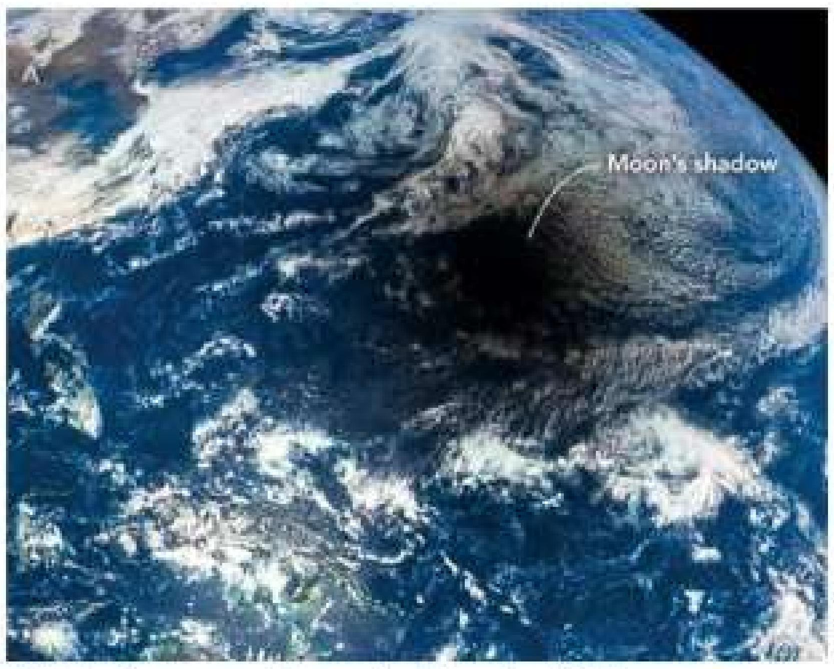
We had visited both poles by 1911 without the life-saving technology scientists rely on today

Have we discovered all the land on Earth?

Lois Hughes

Most scientists agree that we're familiar with almost all of our planet's surface. We don't know for sure, but we can be fairly certain there aren't vast and previously unknown territories waiting to be discovered. Of course, areas exist that we are yet to chart completely.

The closest thing we have to undiscovered terrain is Antarctica. The entire landscape is buried under ice that can reach depths of up to five kilometres. Rocky ground that is yet to be mapped lies hidden far beneath the frost, including the world's sixth-largest lake by volume. Scientists studying our changing climate are drilling down to uncover the hidden region's secrets. **AG**



© NASA

Total eclipses aren't rare, but they're highly localised – as this photo from space shows

Does a solar eclipse often happen on Earth?

Maher Ismail

There's potential for a solar eclipse every new Moon, when we see the Sun and Moon in the same direction, but most months they don't quite line up. Partial eclipses occur a few times per year, and a total eclipse every year or two. They're only visible from a very localised area, which is different each time – you'll have to travel if you want to see several of them. **AM**

© NASA

What's the fastest spacecraft ever?

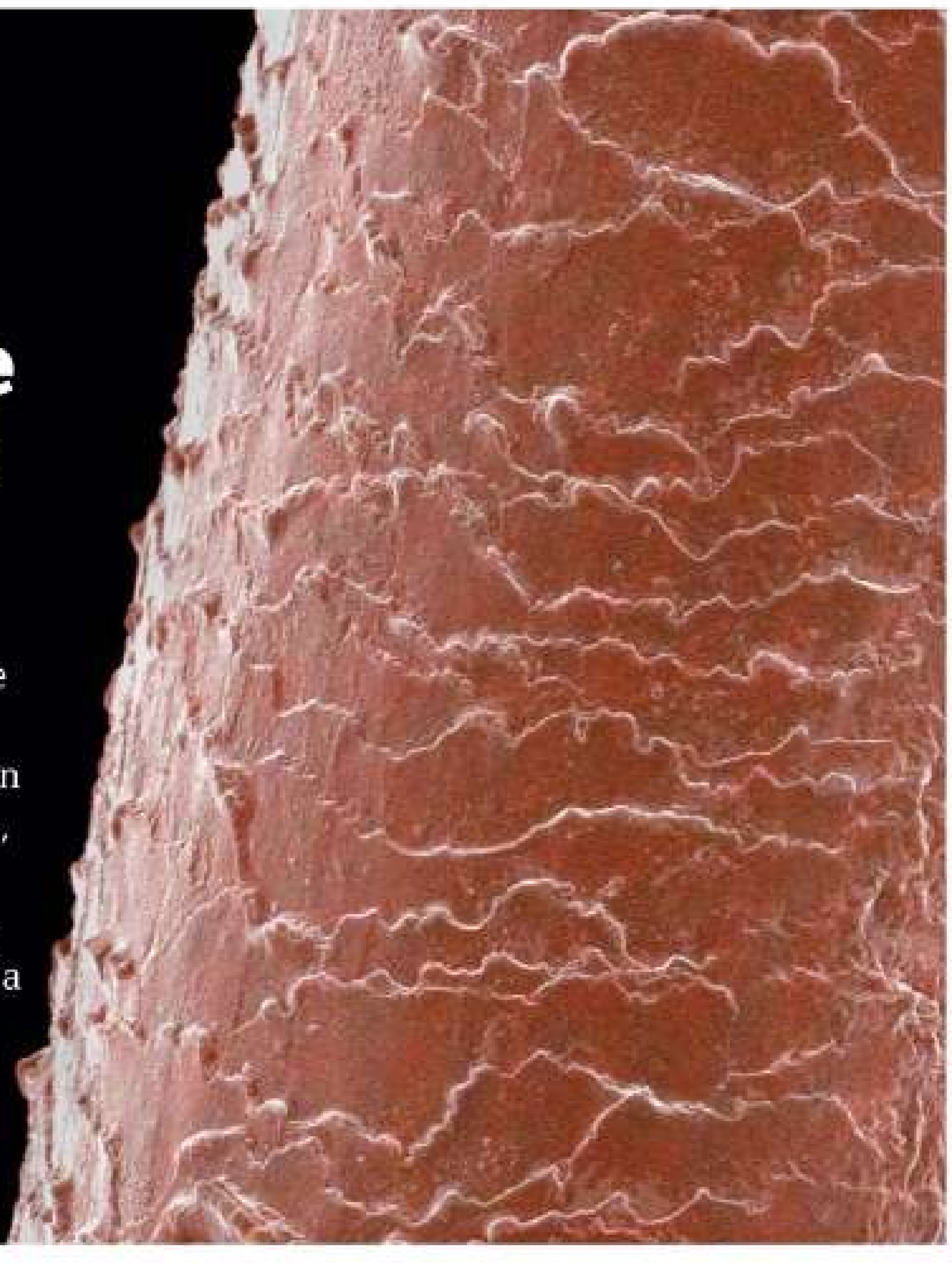
Kieran Roberts

■ For a given energy, a spacecraft travels faster the closer it gets to the Sun. The current record was set by NASA's Parker Solar Probe, which reached a speed of 343,180 kilometres per hour in November 2018 – and it's set to get even faster over the course of the mission. **AM**

How many atoms are required for an object to be visible with no microscope?

James Davies

■ The smallest things people can see are about a hair's breadth, about 0.4 millimetres wide. The spaces between atoms are less than a millionth of this, so visible objects must be a million atoms wide, deep and long, equating to a quintillion atoms. A quintillion is a one followed by 18 zeroes! **AE**



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How do speed cameras work?

Charles Boucher

■ Depending on the type of camera, they utilise radar or detectors in the road to track speed. If they spot you speeding they take a digital image of your vehicle. **MS**

© Getty

Some speed cameras use markers on the road to tell if a vehicle is over the limit

BRAIN DUMP

The skeleton of a plague victim, discovered in a London burial ground, is put on display

© Getty

What has been the world's worst pandemic?

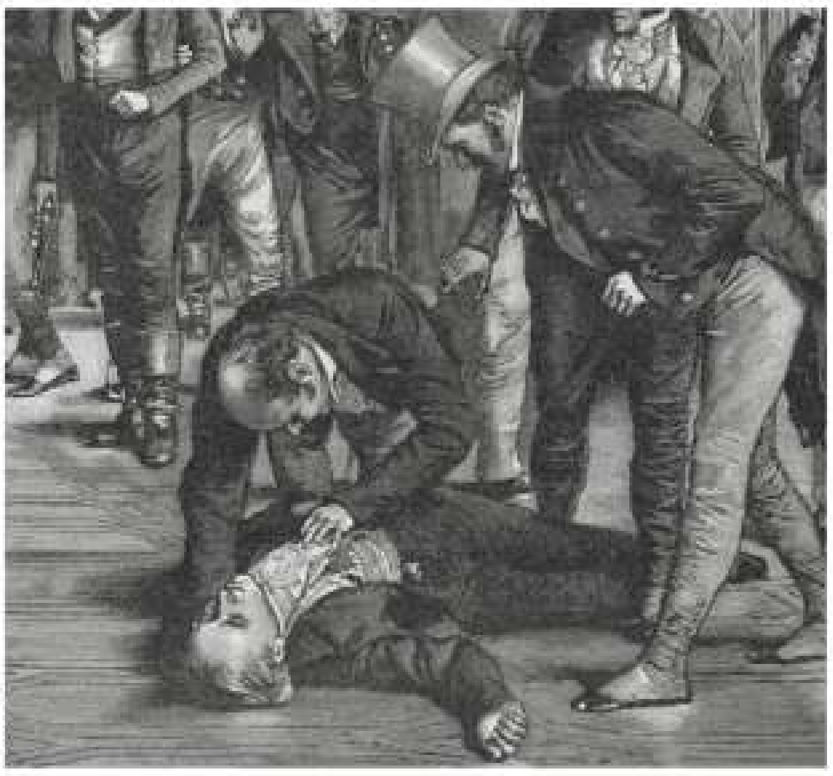
Bruno Souza

■ The bubonic plague, commonly known as the Black Death, ravaged Europe, Africa and Asia from 1331 to 1353 and killed between 75 and 200 million people. It swiftly travelled across the continents via the fleas that lived on the ship rats. The ports were densely populated and so the bacterium thrived and spread throughout the crowded cities. The disease reoccurred in England every few years from 1361 to 1480, reducing England's population by 50 per cent. **JE**

Has a British Prime Minister ever been assassinated?

Luke Carr

■ Spencer Perceval has the dubious honour of being the only British Prime Minister to have been assassinated while in office. He was murdered by John Bellingham on 11 May 1812 as he stepped into the crowded lobby at the Palace of Westminster. **JE**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Source: Wiki / Robert Brewer

Why weren't ships made of metal sooner?

Joe Robertson

■ Although metalwork has existed for centuries for things such as swords and armour, the sheer amount of metal required and the techniques needed to forge them into large ships simply didn't exist until the industrial revolution.

The development of large industrial forges during this era meant the raw materials could now be turned into huge objects such as keels.

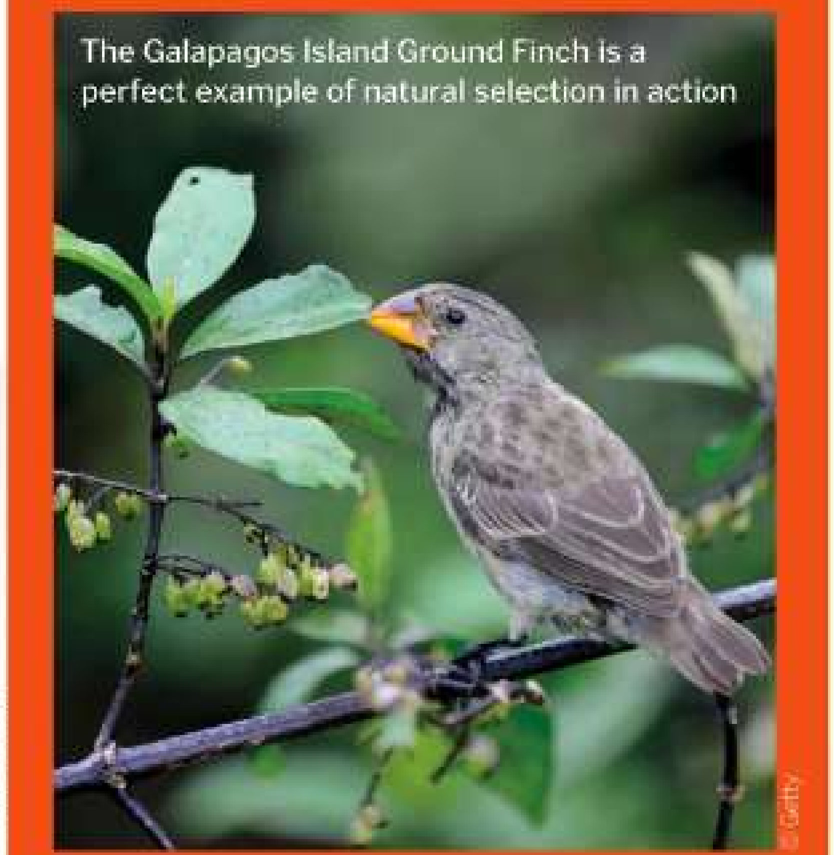
Isambard Brunel's Great Britain, launched in 1843, was the first ship to be built entirely of wrought iron. From the 1880s shipbuilders started to use steel instead of iron, and some were fitted with steam engines. **MS**

© Getty

Has Washington D.C. always been the capital city of the US?

Yasmin Patel

■ New York City, New York, was the first capital of the US under the Constitution before it moved to Philadelphia, Pennsylvania, for ten years, finally moving to Washington in 1800. **JE**


The Galapagos Island Ground Finch is a perfect example of natural selection in action

© Getty

How does natural selection work?

Ali Wurst

■ Natural selection, also known as 'survival of the fittest', is a basic mechanism of evolution. In order for a species to survive it must gradually change in response to its environment and also compete with other organisms for food and other vital resources. If a species fails to pass on its most desirable characteristics to its offspring, then it is likely to become extinct. Organisms must be able to adapt to changing situations such as destruction of habitat, introduction of new predators or limited resources as quickly as possible, but this process can take thousands or even millions of years. **JE**

Why doesn't gold tarnish or get rusty?

Judith West

It's hard for gold to form chemical bonds with other elements. That includes oxygen, which reacts with metals to form rust. Gold's electrons travel near to the speed of light to escape the attractive pull of its heavy nucleus. Relativity, famously described by Einstein, affects electrons travelling this fast. For different atoms to form chemical bonds, their electrons must have similar energies. But the relativistic effect means that gold electrons' energies are almost unique. **AE**

© Getty

Gold doesn't tarnish due to processes described in Einstein's theory of relativity

© NASA

Do other planets outside the Solar System have rings?

Rachel Stewart

As well as Saturn, the Solar System's other giant planets have faint rings, suggesting they're common and may occur around exoplanets. So far, however, no exoplanet rings have been observed. **AM**

© Getty

Bottlenose dolphins use their big brains to solve problems, store complex information and communicate effectively

Can we measure animal IQ?

Alexandra Stevens

There's no standard test to measure how smart an animal is. Instead we study their behaviour and look for actions that only advanced brains are capable of. Tool use, mathematical ability and being able to recognise themselves in a mirror are all signs of a deep thinker. We also measure the size of an animal's brain in comparison to the rest of its body. Apes, dolphins and elephants top the charts on brain size and are all very intelligent animals. **AG**

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Send your questions to...
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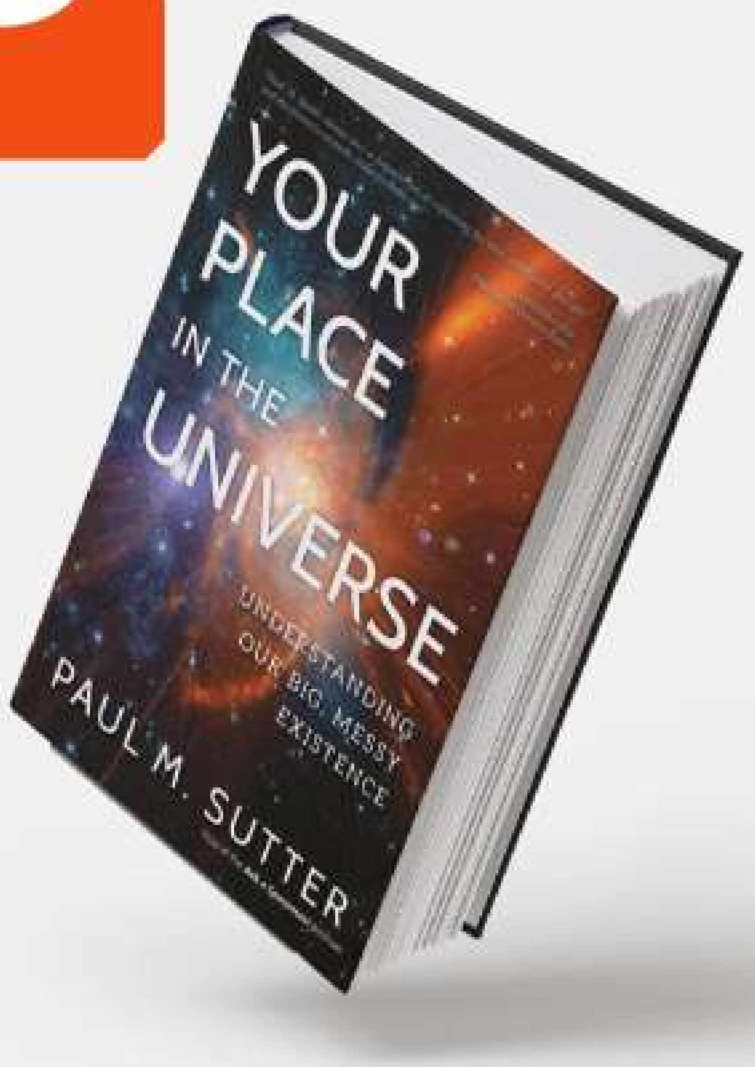
BOOK REVIEWS

The latest releases for curious minds

> "There's an implication that he doesn't believe in the climate emergency

From the author of GREAT BRITISH ECCENTRICS
'A joyous celebration of colourful characters'
DAILY MIRROR
FORGOTTEN SCIENCE
STRANGE IDEAS FROM THE SCRAPHEAP OF HISTORY
S. D. TUCKER


YOUR PLACE IN THE UNIVERSE
UNDERSTANDING OUR BIG, MESSY EXISTENCE
PAUL M. SUTTER

Forgotten Science

Strange ideas certainly play a major role in this book

- Author: **S D Tucker**
- Publisher: **Amberley**
- Price: **£18.99 / $29.95**
- Release: **Out now**

We always hear the tales of scientific success. Einstein, Darwin and Archimedes are all household names, rightly esteemed for their contributions to society. But what about the scientists who didn't grab the headlines? Those conducting experiments that just never quite panned out? *Forgotten Science* aims to tell their stories, and also serves as a comment on scientific practices in general.

While there are plenty of details in here about those failed experiments and their creators, the book also delves into the philosophy of scientific study. Author S D Tucker discusses freethinking, and whether these more outlandish investigations have been lost in an age of global collaboration. It's an interesting point, and one that he returns to throughout.

Unfortunately, some of the author's points aren't so well articulated. While we often praise writers who bring their personal opinions, stories and ideas into their books, it's a slightly different story in *Forgotten Science*. Tucker does bring some entertaining anecdotes and amusing asides to the table here, but sometimes it feels like he veers into 'ranting' territory, or gets caught up in a story and veers away from the topic at hand too much.

There are also a few moments where he throws out some odd and perhaps questionable opinions. There's an implication that he doesn't really believe in the climate emergency, describing it as "an apocalypse that might not happen". At one point he refers to a "needless PC witch-hunt" by "a gaggle of self-righteous harridans, puritanical Twitter mobs and the other such ranks of the professionally offended" who he blames for an honorary professor losing their position after making a joke about women crying in laboratories during a speech. Tucker cites the *Daily Mail* as a source for this – not exactly an esteemed scientific reference point.

These odd inclusions stand out in a book that claims to focus on the study of science. It's a shame, because some of the stories Tucker tells are genuinely interesting, and his deviations on the subject often widen the reader's lens to see a larger picture. Unfortunately, overall the book is too inconsistent, and as a result can be a challenge. ★★★☆☆

Your Place In The Universe

Where we belong

- Author: **Paul M Sutter**
- Publisher: **Prometheus Books**
- Price: **£18.99 / $24**
- Release: **Out now**

Ask a Spaceman! is one of our favourite podcasts, so it's great to see its host, noted astrophysicist Paul M Sutter, transport his ponderings into book form.

One of the contributory factors to the accessibility of this book is its author's determination to replicate the format of the book. Throughout the book, in and among its passages, various questions are posed, which Sutter subsequently uses as a springboard into the discussion of all manner of topics. From antimatter and electrons to vacuum energy and the cosmic dawn, no piece of space dust is left uncovered.

If the last sentence sounds like a daunting array of subject matter, it needn't be. The language is clear and concise, and doesn't require a PhD to decipher. In fact, we'd go as far as to describe this as the ideal book for the adult reader who may have lapsed in their scientific studies post-school life and has since rediscovered a calling to re-engage with this particular topic.

In keeping things accessible, there's always the risk of simplifying topics that don't really lend themselves to this process, but it's hard to detect any of that going on here. In short, it deserves the benefit of any doubt. ★★★★★

The History of Space Exploration

Travelling the timeline

- Author: **Roger D Launius**
- Publisher: **Thames & Hudson**
- Price: **£24.95 (approx $35)**
- Release: **Out now**

The History of
SPACE EXPLORATION
Thames & Hudson

As a former chief historian of NASA, there can't be many people more qualified than Roger D Launius to write a chronology of our progress in the field of space exploration. Which is just as well, considering what we're writing about here.

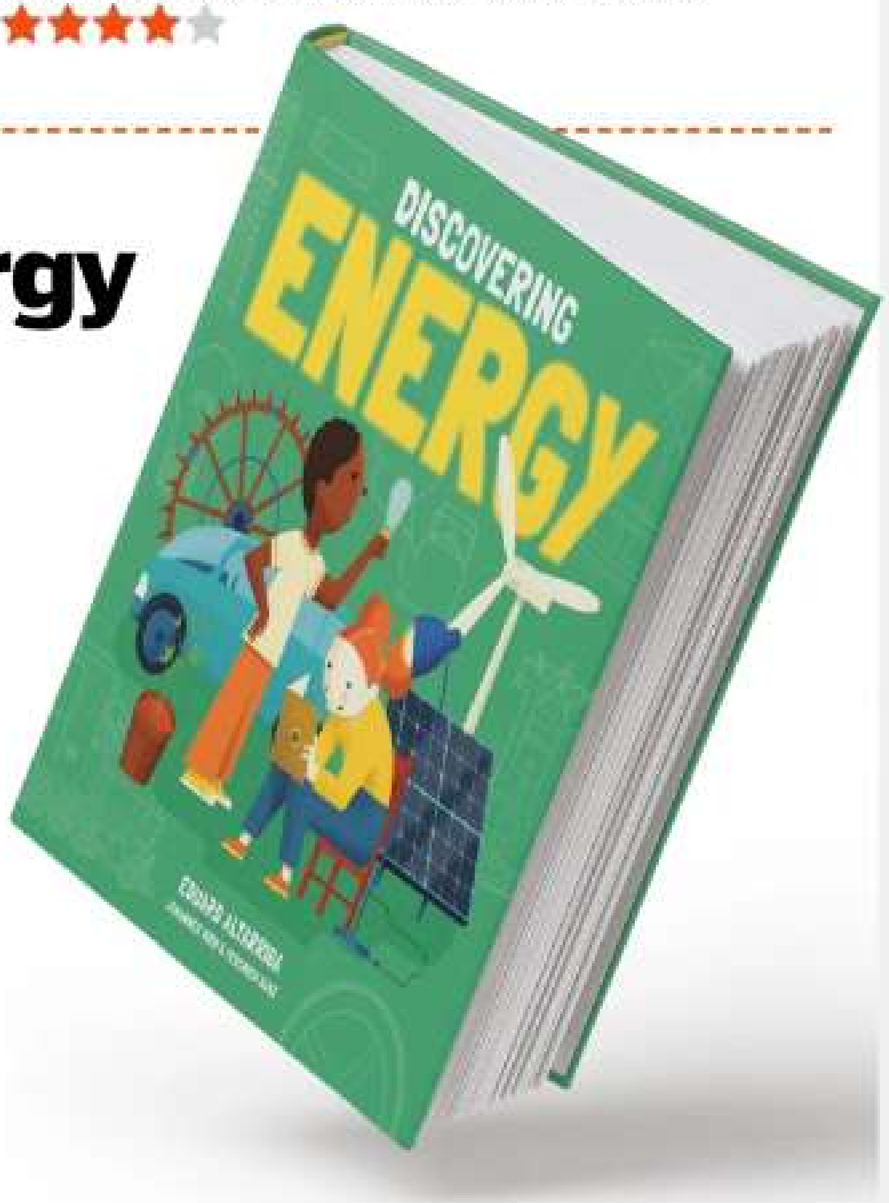
Charting the earliest speculations of individuals like Bernard Le Bovier and civilisations like the Aztecs to the first experiments with rocket devices and our subsequent flight into the final frontier, this is nothing if not comprehensive. Each development is assigned a decent-sized passage of writing, with accompanying images visualising the route for us.

The format is a bit repetitive, which might at times make this a book more suitable for diving in and out of than devouring in one sitting, but the perfunctory design shouldn't overshadow what serves as a fountain of information. No frills, but there's not a lot wrong with that. ★★★★☆

Discovering Energy

We've got the power

- Author: **Eduard Altarriba, Johannes Hirn, Verónica Sanz**
- Publisher: **Button Books**
- Price: **£12.99 / $17.99**
- Release: **Out now**



If Eduard Altarriba has illustrated it, then there's a good chance we'll be reading it. We're frequently captivated by the simplistic yet colourful and evocative images that he produces, which makes us delighted that we find yet another of his books in our hands.

Penned by Johannes Hirn and Verónica Sanz, this provides a child's guide to the topic of energy, namely what it is, how it's used and, most importantly, how it works.

The book touches on the various types of energy, such as solar, wind, water and electricity; the various structures and devices they power – such as batteries and combustion engines – and the residue they leave behind – steam and pollution among them. Moreover, our understanding of the subject constantly developing, attention is paid to how energy can be adapted to help us further in the future, notably in the field of space exploration.

As a book that's image-led rather than text-heavy, you'd probably be better off looking elsewhere for a more in-depth study of this. For younger readers, however, this provides the perfect encouragement to develop more of an interest in what can seem like a rather broad and daunting area of study. ★★★★☆

Build Your Own Gaming PC

Game on

- Author: **Adam Barnes**
- Publisher: **Haynes**
- Price: **£22.99 / $29.95**
- Release: **Out now**

For its latest manual, the good folks at Haynes have taken a relatively leftfield turn to what they usually cover, in this case lending their expertise to the quest to put together the perfect gaming PC.

If this is something you have already attempted then the chances are that you already know what you're doing, but this starts at the beginning anyway. From running through the tools of the trade and the components you really shouldn't neglect to the process of actually putting it together and the major dos and don'ts, no stone is left unturned to make sure you don't take any shortcuts while creating the kind of games machine to make Xboxes and PlayStations look on aghast.

It's fairly niche as far as Haynes manuals go, but that's not necessarily a bad thing. If you fit its target audience then you will likely get a lot out of this. ★★★★★

Haynes
Build your own
Gaming PC
Haynes
Adam Barnes

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

E	T	E	F	A	W	X	M	I	V	N	O	L	F	V
Z	R	A	L	L	Y	O	Y	E	A	S	R	T	A	I
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N	T	W	I	E	R	E	T	O	O	C	S	Z	R	W
G	S	L	A	I	V	H	J	Y	E	A	U	T	X	C

FIND THE FOLLOWING WORDS...

RALLY
SCOOTER
REMEMBER
OCEAN
SECURITY
LEVITATE
SILVER
UNIVERSE
DECOMPRESS
SOLAR
COW
VICTORIAN

Quickfire questions

Q1 Typically, how much can a WRC car cost?

- ○ £100,000
- ○ £50,000
- ○ £10,000
- ○ £500,000

Q2 Roughly how much data can the human brain store?

- ○ 100 gigabytes
- ○ 100 megabytes
- ○ 100 terabytes
- ○ 100 kilobytes

Q3 What's the study of ocean depth called?

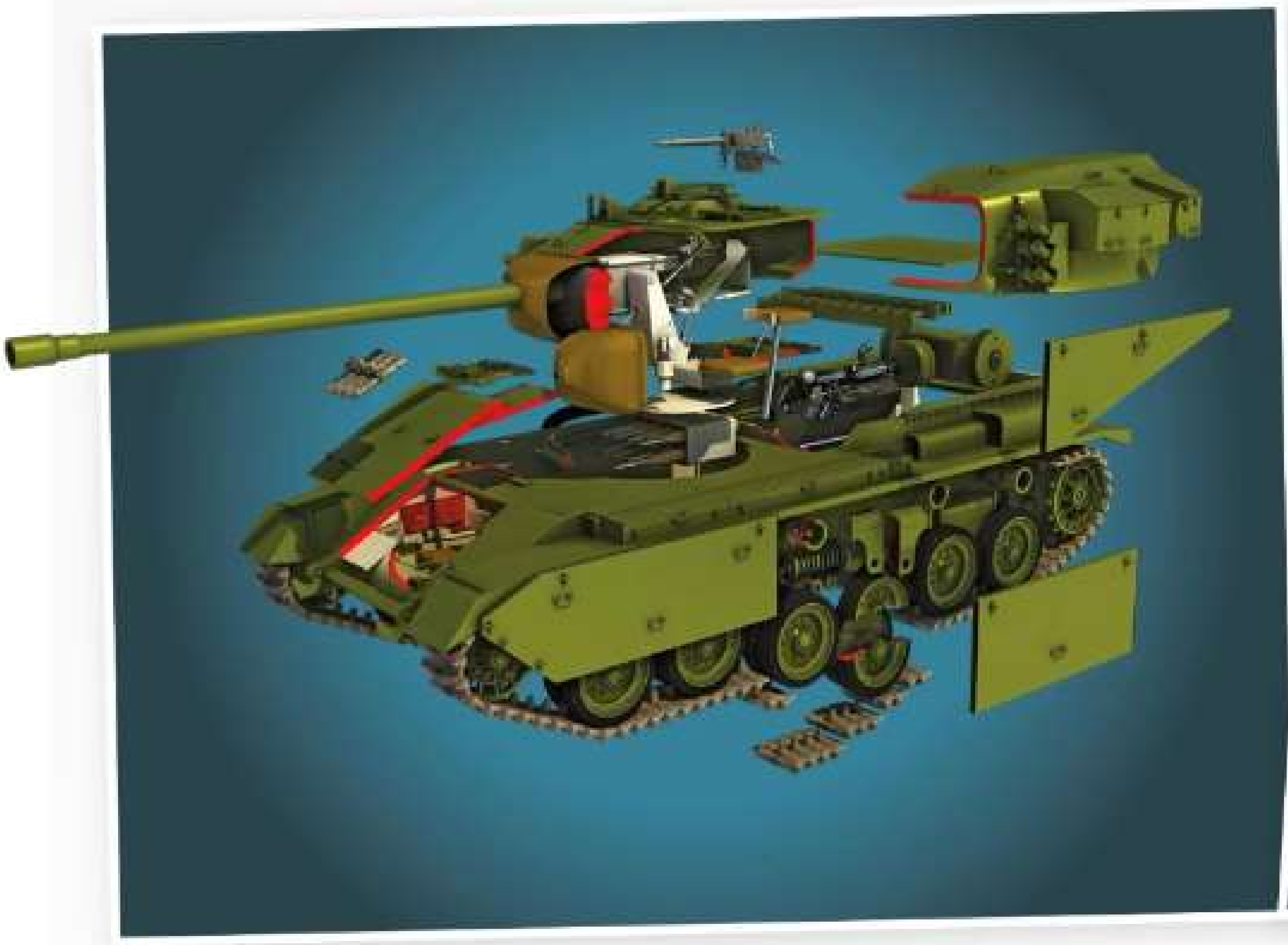
- ○ Topography
- ○ Waterology
- ○ Seaology
- ○ Bathymetry

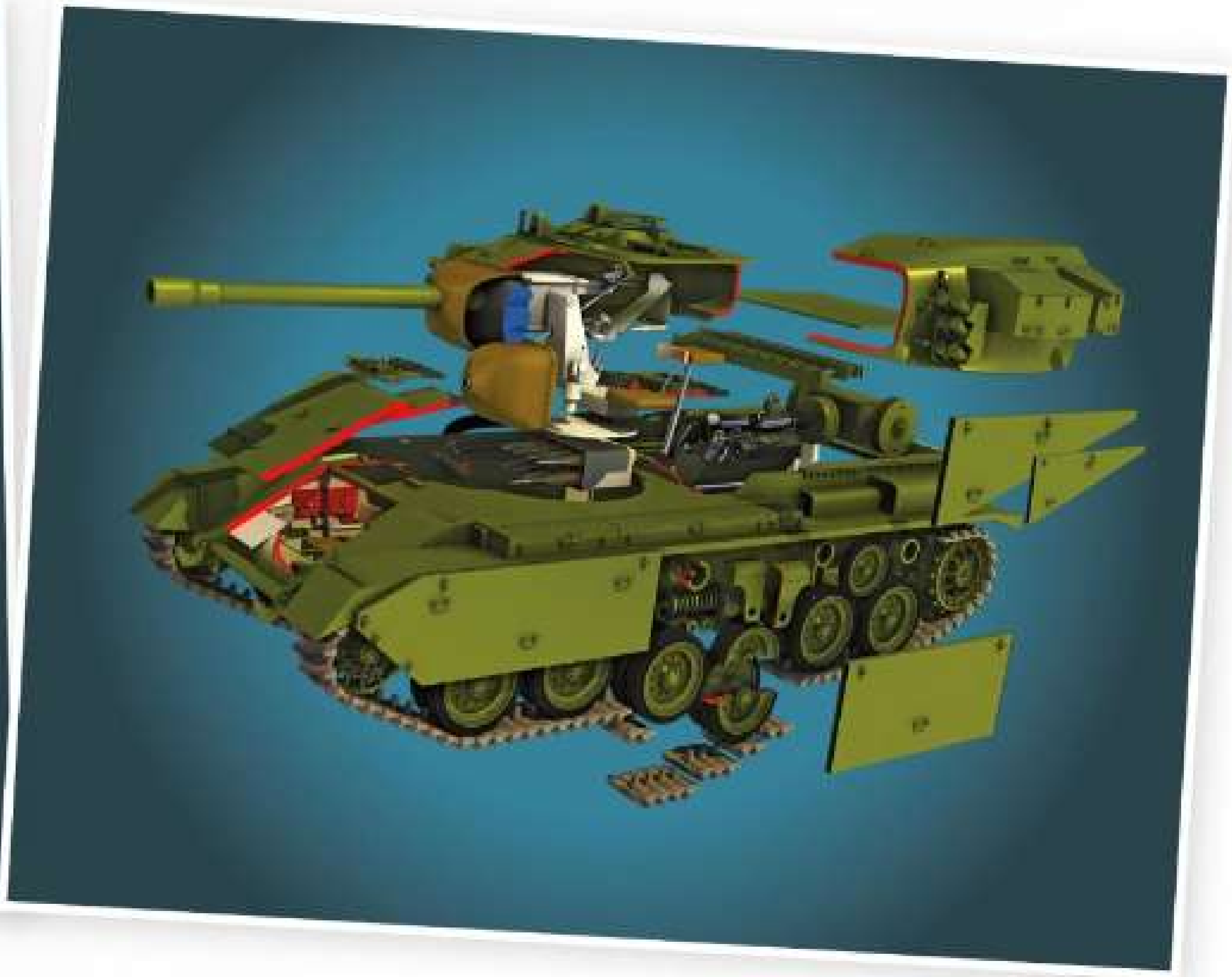
Q4 Why were crinoline dresses deadly?

- ○ They were made of radioactive plutonium
- ○ They were flammable
- ○ They were very tight
- ○ They attracted snakes

Spot the difference

See if you can find all six changes we've made to the image on the right





Sudoku

Complete the grid so that each row, column and 3x3 box contain the numbers 1 to 9

EASY

2	4		6	9		8	5	
9			5		8	4		
6		5	4		1	7		
4	6			8		1		
						2		
3	5	2		4	6			8
5	9	8		1	3		4	
	2	6		5	4		8	1
1					2			

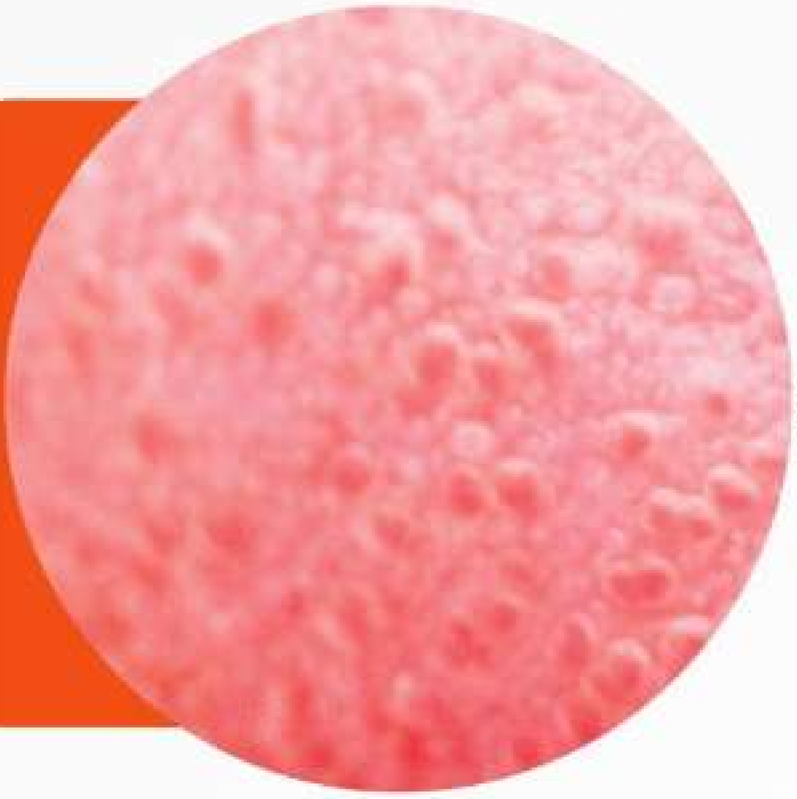
DIFFICULT

	7					9		
			3					
					1	8		
							1	
	6					2	5	
2	1		9	7				
3		1	7					
9	2	7	8	6		4	3	
5				2				8

What is it?

Hint: If you don't own these, then you have very poor taste.

A ....



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For more brain teasers and the chance to test your problem-solving skills, enjoy our **Mensa Puzzle Book**, which is packed with challenging problems and puzzles designed by experts.

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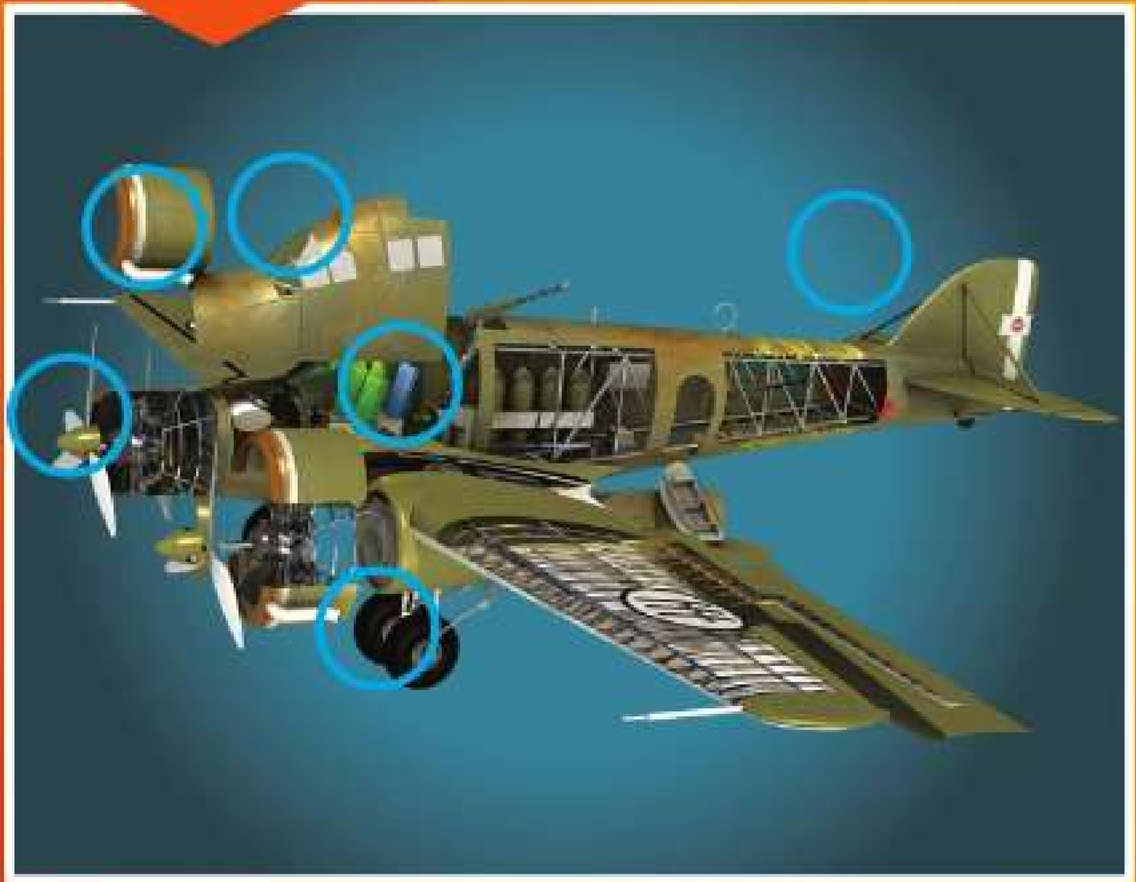


Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 1964

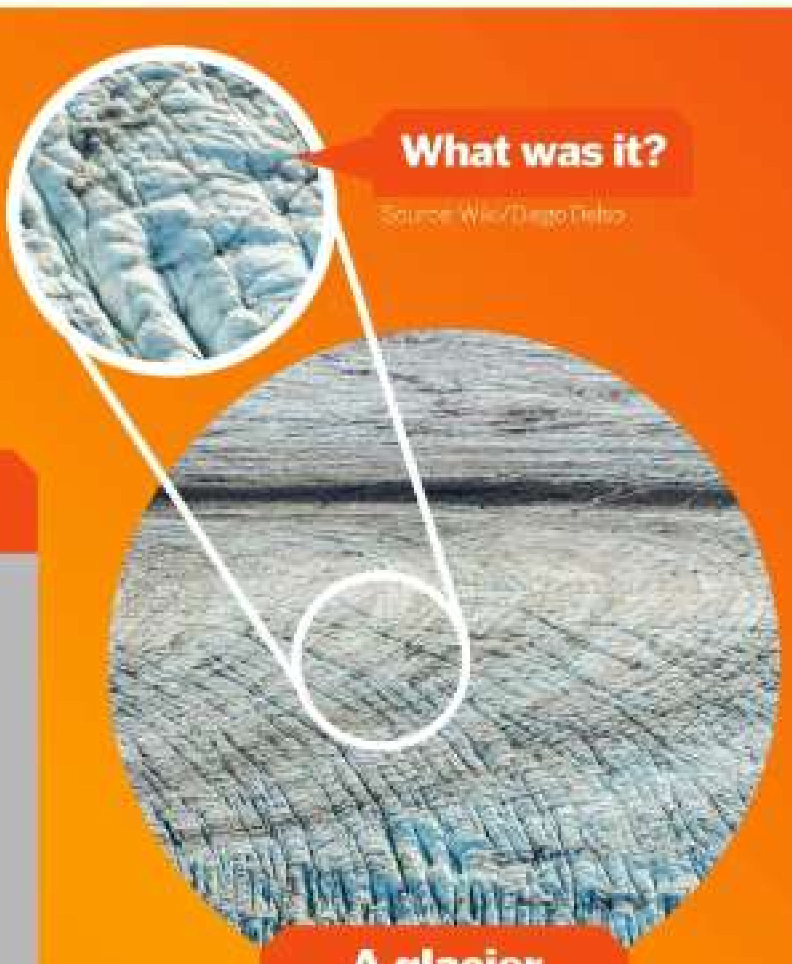
Q2 5cm

Q3 Iron-nickel

Q4 350,000 years

What was it?

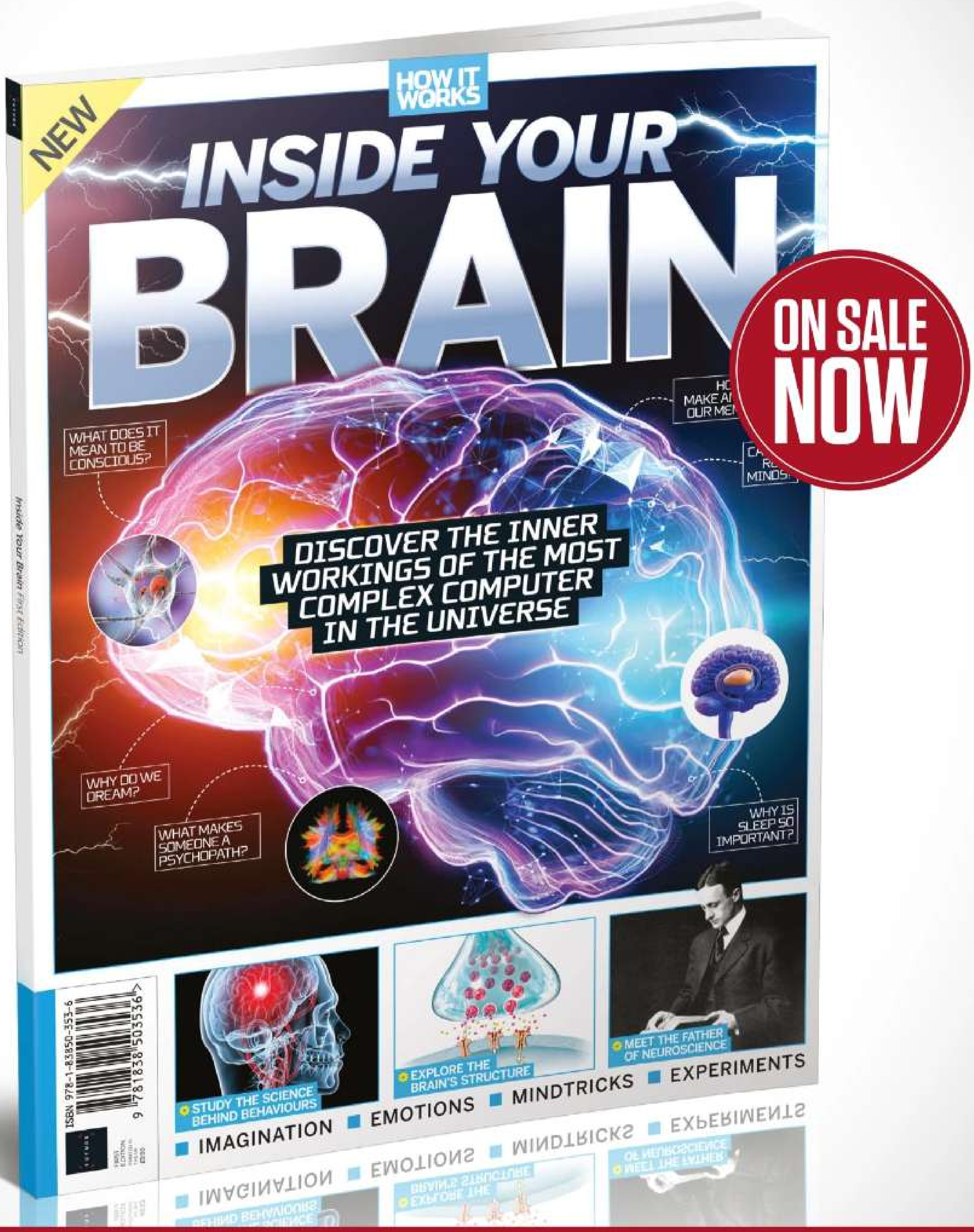
Source: Wiki/Diego Delso



A glacier

EXPLORE THE MANY WONDERS OF THE HUMAN BRAIN

Have you ever wondered why we dream? Confused by what it means to be conscious? Intrigued by the latest cutting-edge brain technology? Well wonder no more, for all the answers to your brain questions can be found in this book!



NEW
HOW IT WORKS
INSIDE YOUR BRAIN
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DISCOVER THE INNER WORKINGS OF THE MOST COMPLEX COMPUTER IN THE UNIVERSE
WHY DO WE DREAM?
WHAT MAKES SOMEONE A PSYCHOPATH?
WHY IS SLEEP SO IMPORTANT?
STUDY THE SCIENCE BEHIND BEHAVIOURS
EXPLORE THE BRAIN'S STRUCTURE
MEET THE FATHER OF NEUROSCIENCE
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EMOTIONS
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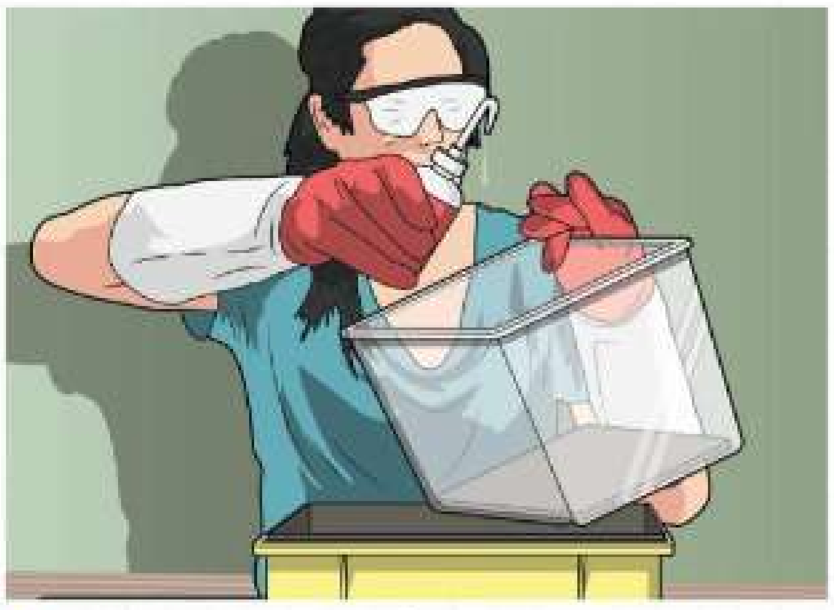
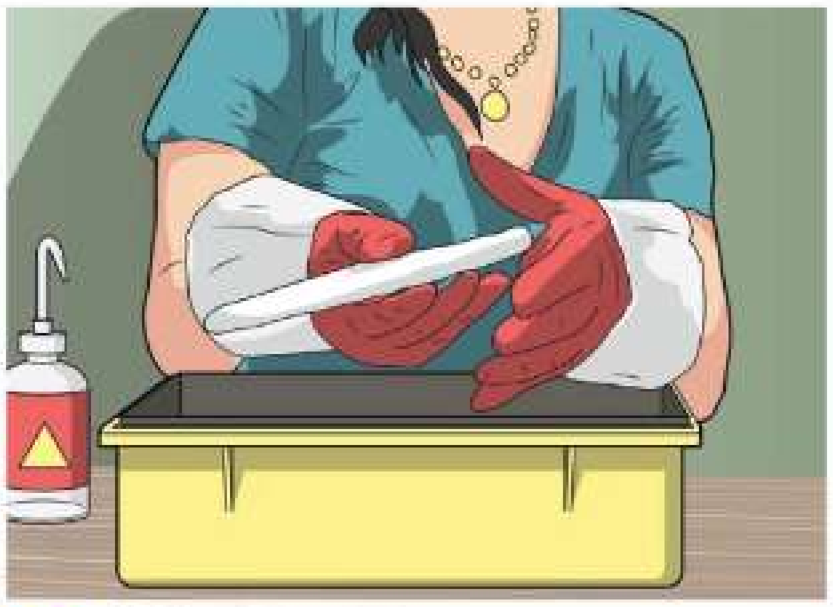
How to see cosmic rays

Create a cloud chamber and watch subatomic particles zoom through the air in front of you



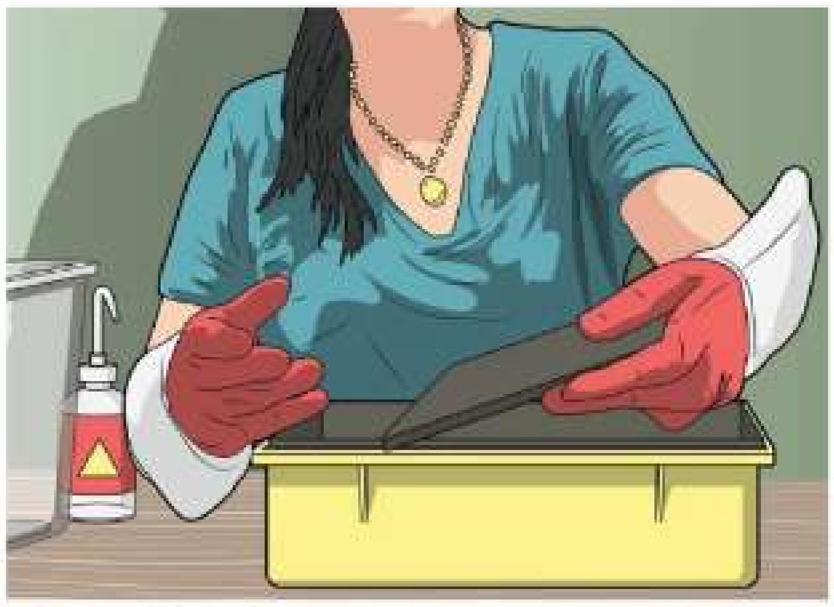
1 Prepare your tank

First, you'll need to find a large, rectangular tank – like a fish tank. Cut out a piece of felt the same size at the top and stick it inside the tank, then soak it in isopropyl alcohol.



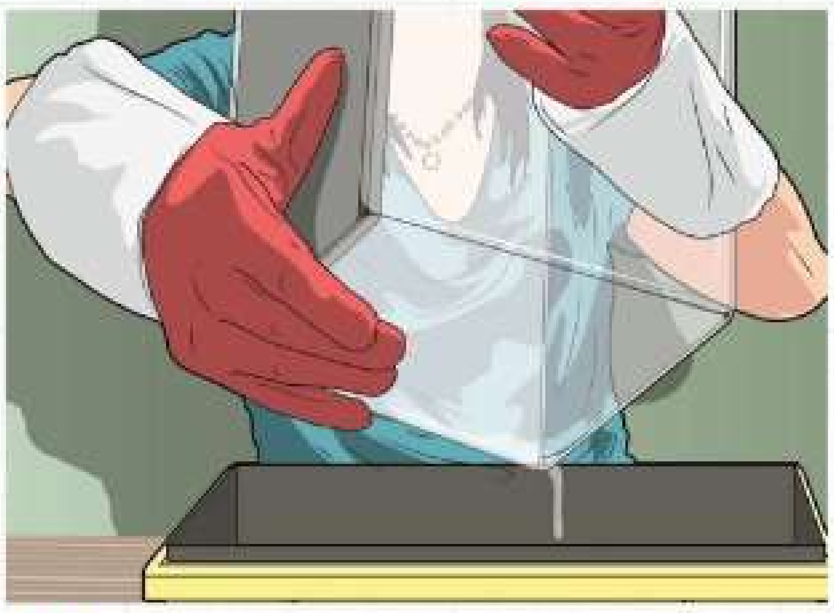
2 Add dry ice

Now ask an adult to put on some thick gloves and place some dry ice in a large, well-insulated base. Dry ice is solidified carbon dioxide, and it needs to be very cold to stay solid, so be careful.



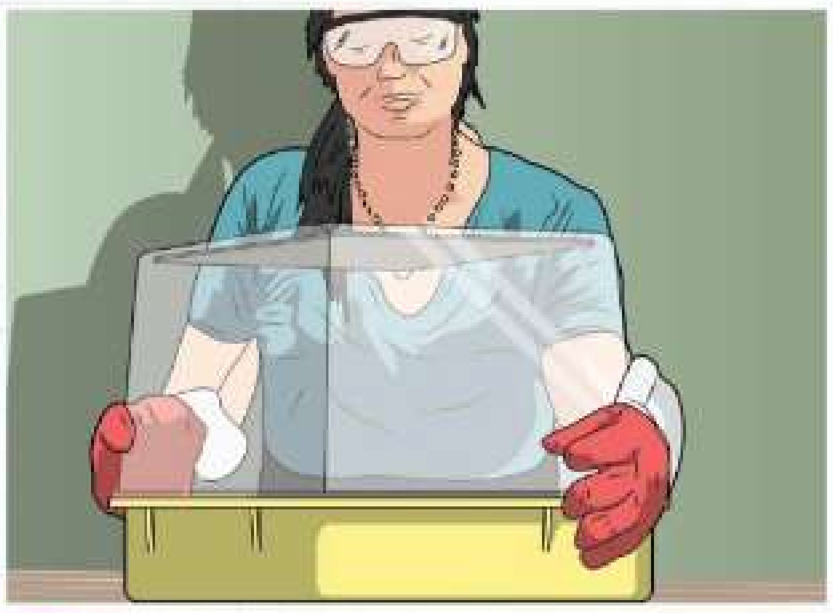
3 Cool the base

Now take the lid of your fish tank – ideally one that's dark in colour – and place it on top of the dry ice. Let it sit there until it cools to the temperature of the dry ice.



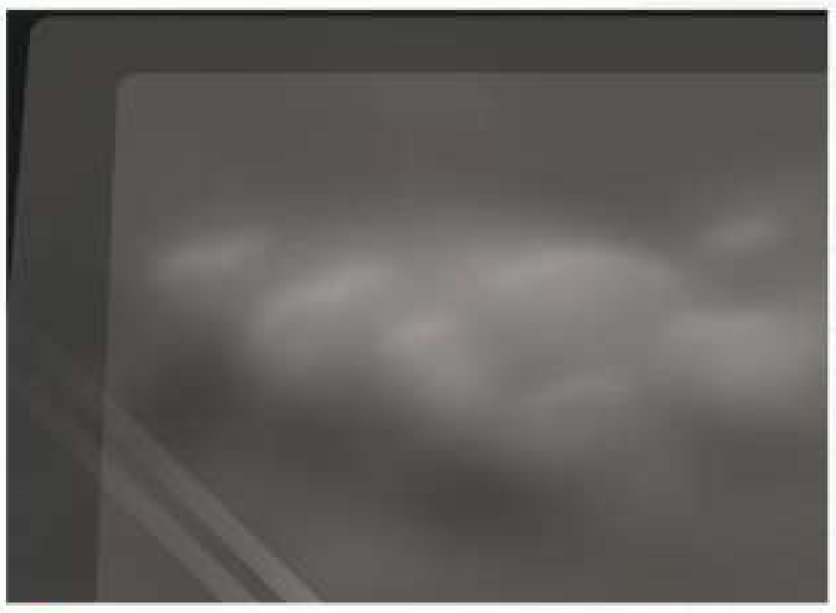
4 Seal it off

If you have any excess alcohol in your fish tank, pour it out in a rectangle on the cooled base. When you place the fish tank on top, it should form a seal with the liquid.



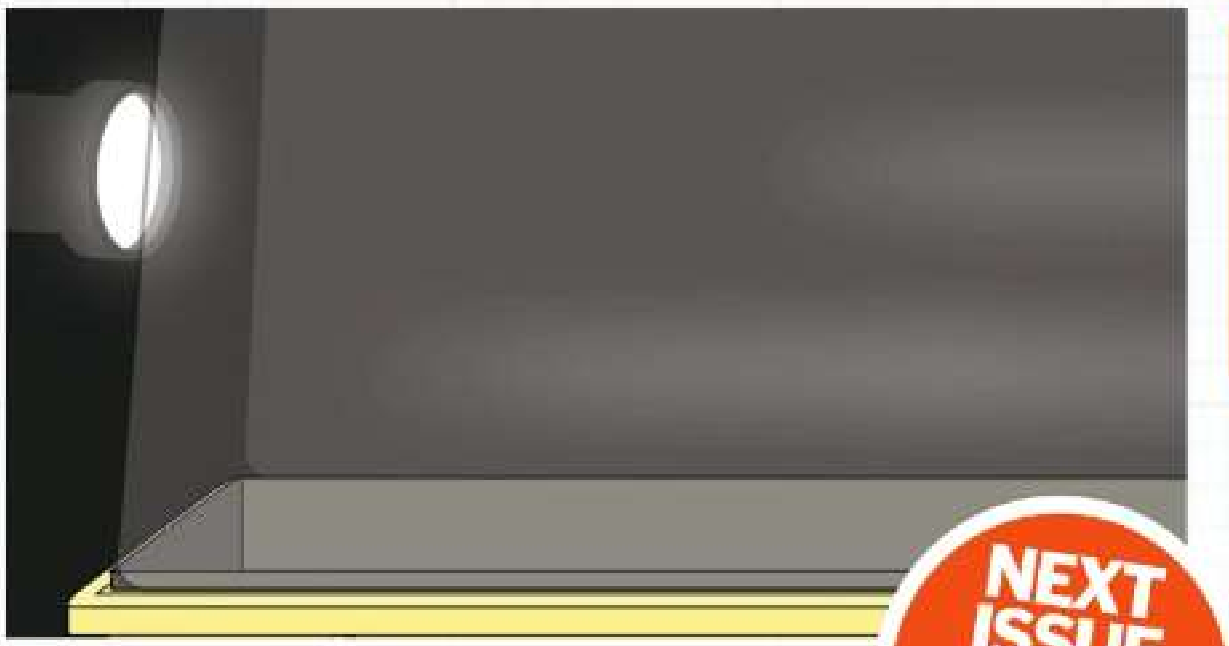
5 Waiting game

Place the fish tank onto the lid and turn the lights out. We now need to wait for the room-temperature alcohol to evaporate into the air inside the fish tank.



6 Watch it cool

As the evaporated alcohol reaches the bottom of the fish tank, the dry ice begins to cool it. As it cools, it wants to form a liquid – so tiny droplets form into a cloud.



7 Lights out

Shine a torch in through the side of the fish tank. You should see the cloud, but you should also see lines appearing in the cloud. These are particles!

© Illustrations by Ed Crooks

SUMMARY…

Particles from space are constantly bombarding the Earth, passing through us on their journey through the universe. As they zoom through the cloud chamber, they cause disturbances in the gas, ionising the gas molecules. This makes them clump together to form tiny droplets. Different types of particles form different kinds of tracks.

> "You should see lines appearing in the cloud"

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

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NEXT ISSUE
Make rainbow raindrops and test oil density

INBOX

Speak your mind...

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com

HIW was a desirable prize at this school fête

© Kerry

Christmas fête fun

Dear HIW,

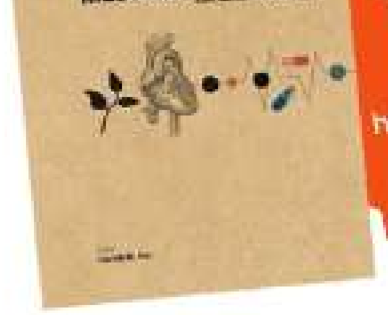
I created a 'balloon pop' stall at our Christmas fête last week. Basically kids pay 50p to pop a balloon, and if the raffle ticket number inside it is even, they win a prize – a magazine!

All 100 balloons were popped within an hour and I banked the PTA £50. That may not seem a lot to you, but to us it's totally great, and all it cost us was the price of balloons! I even recall two dads popping balloons because they wanted a particular edition of How It Works magazine!

Thank you so much for supporting us, it really made a difference. I had the most popular stall by a long way.

Kerry, PTA Iver Heath Junior School

Thank you to Iver Heath Junior School for sharing this picture of its Christmas fundraising event. It sounds like great fun and we loved hearing about the head-to-head battles for a copy of How It Works.



WIN!

30-SECOND MEDICINE

50 crucial milestones in the history of health, the treatments and technologies, each explained in less time than it takes to read this page.

Letter of the month

Engines

Dear HIW,

How do rotary engines work differently to regular combustion engines?

Thank you

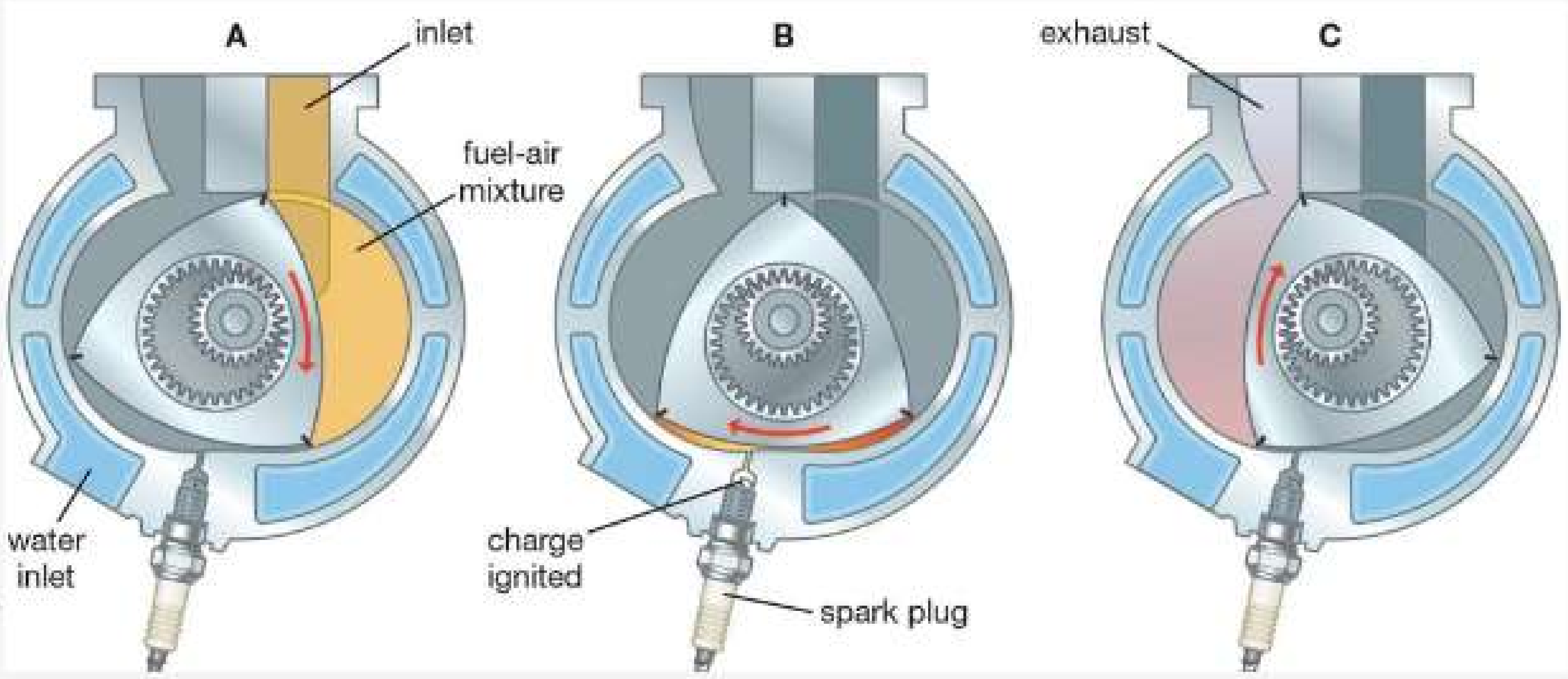
Leo

Rotary engines were the early combustion engines used in cars, and as you have noted, these work differently to the conventional piston combustion engine.

A piston engine uses the same space to carry out four different jobs: intake, combustion, compression and exhaust. These processes occur alternately in a chain system. Meanwhile, rotary engines require the same four actions to take place, but in their own separate compartments of the cylinder. Both engine types use pressure from the burning of fuel and air, but it is utilised in different ways. In piston engines, the pressure builds up inside the cylinder and causes pistons inside to move back and forth. This motion is converted into a rotation to move vehicles.

In rotary engines, however, the resulting force is kept in compartments separated by a triangular structure. Three separate volumes of gas expand and contract to turn the triangular containers around, drawing air and fuel into the engine to generate power.

When a mixture of fuel and air is pumped through the engine's opening, it is forced into a space between the sides of the rotor. Being turned around inside the barrel, the fuel is ignited. This causes the gases to expand, and increased pressure continues to turn the rotor and produce power.



© Getty

This diagram shows how the triangle rotor turns – similar to a spirograph

© Pixabay/Arek Socha

At its closest the Moon is 363,000 kilometres away from Earth

Lunar lasers

Dear HIW,

If you stood on the Moon facing Earth in the centre of the laser beam that is used to determine its distance, how would the beam change the look of Earth?

Colin

Lasers beamed from our planet are aimed at a reflective device placed on the Moon. By shooting the lasers in intermittent pulses, these are able to be counted and timed upon their return back to Earth. The time taken for the laser to return is used as a way to compare these great distances. While this can be detected for data gathering, the signal of these lasers is too weak to be viewed by the human eye. Laser ranging is a method used to calculate distance rather than physically see distance. If you were to watch Earth from the Moon, you may see it gradually change in size over time as it gets closer. In the sky, the Earth would take up 13-times more space when viewed from the Moon as the Moon does from our planet.

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NEXT ISSUE...
Issue 135 on sale
20 FEB 2020

Crow habits

Dear HIW,
Do young crows feed and take care of their old and disabled parents?
Lily Lin (Malaysia)

Across the globe, you can find crows living in large families of around 15, building up a network of trust and care. Many stay nesting where they are born, except for in winter months when they need to migrate. Spending large portions of their lives with their parents, crows have been observed looking out for each other, helping the injured and vulnerable among the group.

These seemingly caring birds not only look after their immediate family, but have been documented taking in adopted orphans and looking after them too. Even in cases where parents and other family members are permanently disabled, crows can take on the role of carer for life. As well as bringing food to their parents, crows often help them out by finding food for baby crows and guarding the nest to keep their family safe.

© Getty

Crows are cooperative breeders, meaning they live close to their nest, defending their family

Inside Netflix

Dear HIW,
How does Netflix work?
Oisin

When Netflix was launched in 1997, there were mixed feelings about the idea. DVDs were new and it seemed the world wasn't quite ready for online streaming. Today, Netflix has become one of the most popular platforms for TV shows, films and documentaries. Its constant updates provide a range of viewing choices, and it is able to recommend things for individual users. To do this, Netflix analyses your history and uses a specially designed algorithm to suggest tailored entertainment.

First it searches for people who have rated the same film. After these have been filtered down, it finds other common film ratings between these users. The more people rating highly for the same films, and the more films that these correlations apply to, the more accurate a prediction Netflix can make as to which other films an individual will also enjoy.

© Pixabay

Netflix uses a content delivery network to store its masses of content

What's happening on... social media?

This month we asked you what you think the coolest piece of tech was from 2019

@ChloeMayWrites
"I don't have one (yet) but I think the coolest thing is the Click & Grow Smart Garden, which allows you to grow your own basil indoors (so that you don't have to keep buying it from the supermarket only to have it wilt just days later) #SaveThePlanet #GrowYourOwn"

@2Shelley09
"The Garmin Forerunner 935!"

@angep1969
"I think the new folding mobiles are quite clever"

HOW IT WORKS
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FAST FACTS

Amazing trivia to blow your mind

13.799 BILLION YEARS

THE APPROXIMATE AGE OF THE UNIVERSE UNDER THE BIG BANG THEORY

$22 BILLION

ITER IS SPENDING A FORTUNE ON A FUSION REACTOR IN FRANCE, SCHEDULED FOR 2025

56.7KG

DAIRY COWS NEED TO PRODUCE AN ENORMOUS AMOUNT OF SALIVA EVERY DAY

82.8 MILES

ELECTRIC KICK SCOOTERS TRAVEL 20-TIMES FURTHER THAN AN ELECTRIC CAR ON 1 KWH OF POWER

85%

THE VAST MAJORITY OF THE WORLD'S SEABEDS ARE UNEXPLORED AND UNMAPPED

THE DRIVING REACTION TIME OF PROFESSIONAL RACING DRIVERS IS HALF THAT OF THE AVERAGE PERSON

MALE ASTRONAUTS ARE MORE LIKELY TO SUFFER VISUAL IMPAIRMENT THAN FEMALE ASTRONAUTS

1.4 MILLION CARATS

IN 2018 DE BEERS EXTRACTED A HUGE NUMBER OF DIAMONDS FROM THE SEABED AROUND NAMIBIA

IN VICTORIAN TIMES, UNSCRUPULOUS GROCERS PUT RED LEAD INTO CAYENNE PEPPER TO INCREASE PROFITS

CAFFEINE CAN HELP TO INCREASE ALERTNESS, BUT NOT IMPROVE YOUR MEMORY

9 METRES

THE LARGEST-KNOWN FEATHERED DINOSAUR, YUTYRANNUS, WAS TWICE AS LONG AS A CAR

357.7 MILLION TONNES

THE AMOUNT OF GENETICALLY MODIFIED CORN PRODUCED WORLDWIDE, 1996 TO 2015

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LANE 2
LAP 002/010
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